Climate Model Assessment Update

STAR 2/27/20

Gary Shenk – USGS/CBPO

Lew Linker, Gopal Bhatt, Richard Tian, Isabella Bertani, Cuiyin Wu

…and many others

Principals' Staff Committee Decisions in 2017 and 2018

- No change in the WIPIII target loads until 2025, unless PSC decides to do otherwise.
- Adjust the 2022-2023 milestones for climate change which could mean:
    - Lower the load target
    - Keep the same WIPIII targets and designate an additional climate reduction, perhaps with a different goal date
    - Something else

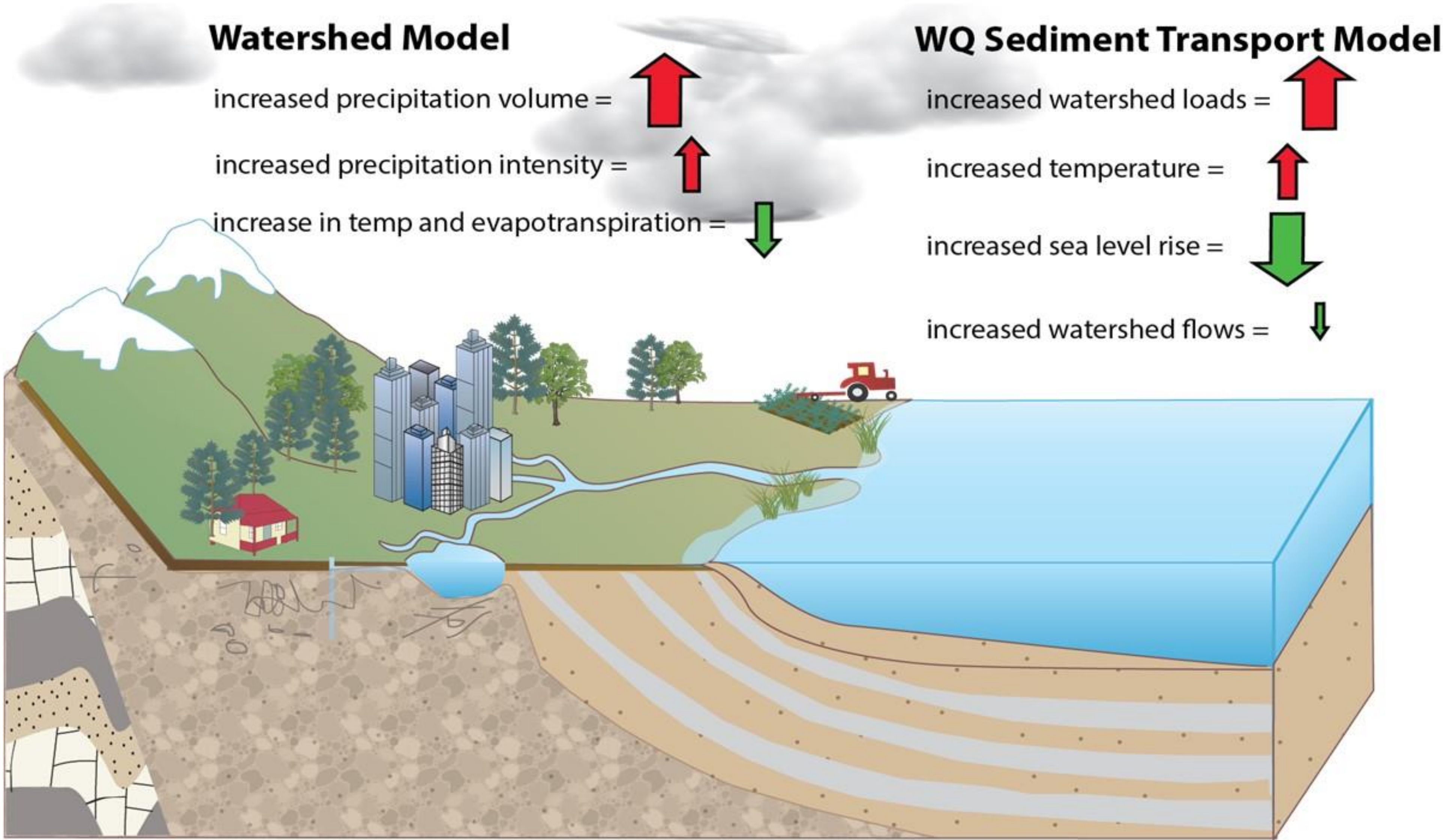
Climate is a moving target

- TMDL is based on hydrology centered on 1995
- TMDL end date is 2025

- **How has an ‘average hydrologic condition’ changed between 1995 and 2025**

- Look at 2035, 2045, and 2055

Components of Climate Change – Effect on Tidal Dissolved Oxygen



CBP Climate Work Plan

Plan — 2018

STAC Workshop

Climate Resiliency WG to investigate BMP response

Jurisdictions provide narrative in WIP3s on climate strategies

Modeling WG develop climate scenarios

Model — 2019

Modeling WG, direct Modeling team to develop climate change assessment for TMDL with input from CRWG and WQGIT

Review — 2020

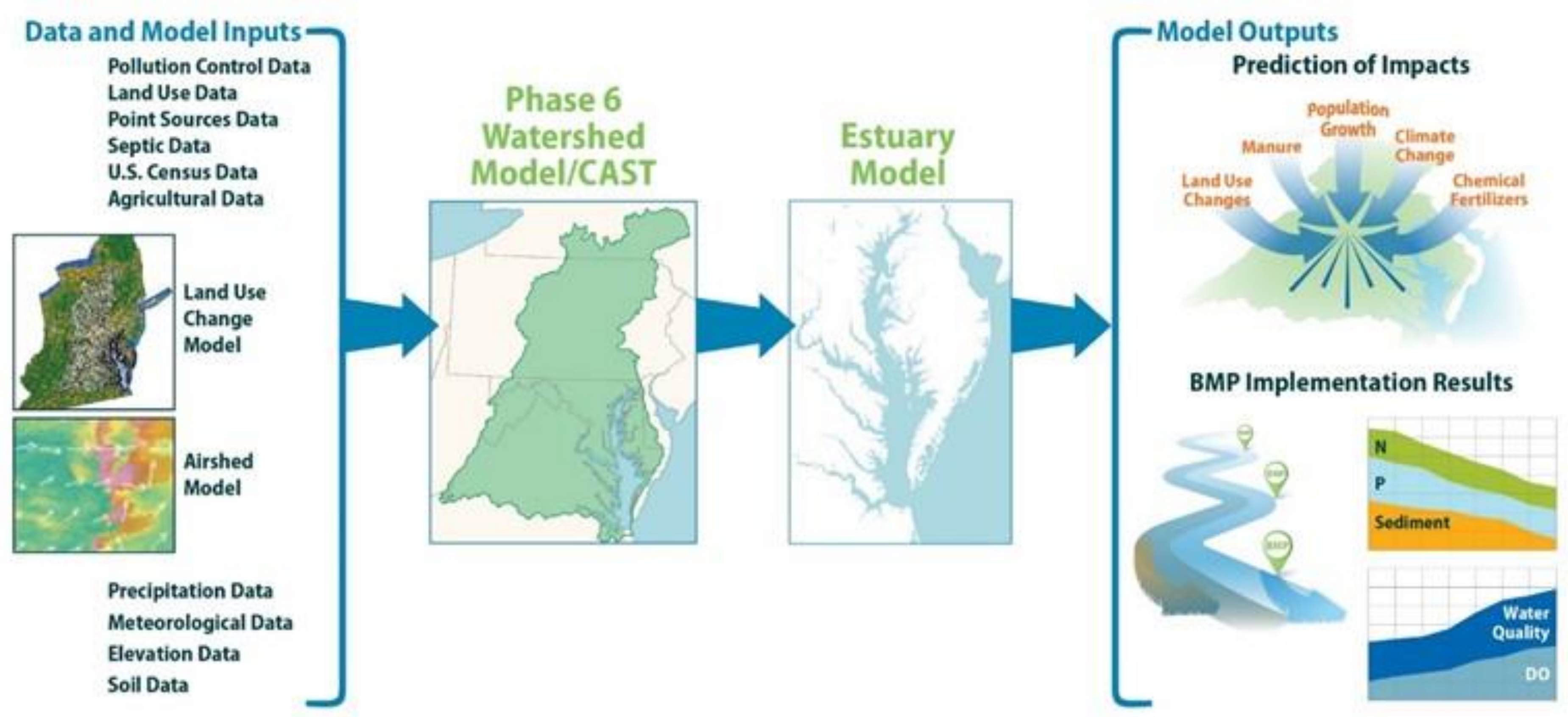
Technical Review of Models

Discuss options with the WQGIT, MB, and PSC

Decide — 2021

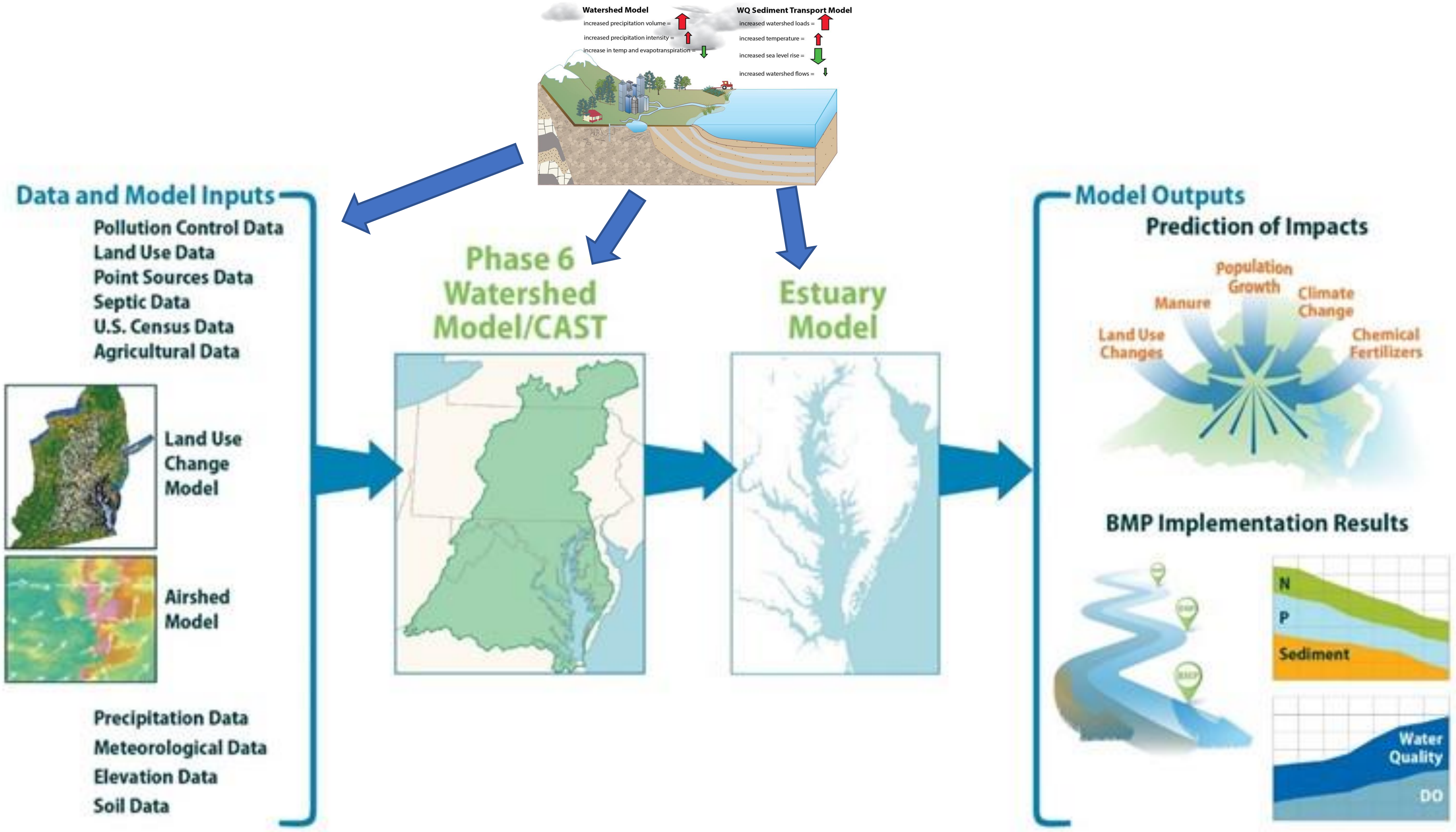
Climate change considerations will be implemented into the 2022-2023 milestones.

CBP Models



Data and Model Inputs
Pollution Control Data
Land Use Data
Point Sources Data
Septic Data
U.S. Census Data
Agricultural Data
Land Use Change Model
Airshed Model
Precipitation Data
Meteorological Data
Elevation Data
Soil Data
Phase 6 Watershed Model/CAST
Estuary Model
Model Outputs
Prediction of Impacts
Population Growth
Manure
Climate Change
Land Use Changes
Chemical Fertilizers
BMP Implementation Results
N
P
Sediment
Water Quality
DO

CBP Models



Watershed Model
increased precipitation volume =
increased precipitation intensity =
increase in temp and evapotranspiration =
WQ Sediment Transport Model
increased watershed loads =
increased temperature =
increased sea level rise =
increased watershed flows =
Data and Model Inputs
Pollution Control Data
Land Use Data
Point Sources Data
Septic Data
U.S. Census Data
Agricultural Data
Land Use Change Model
Airshed Model
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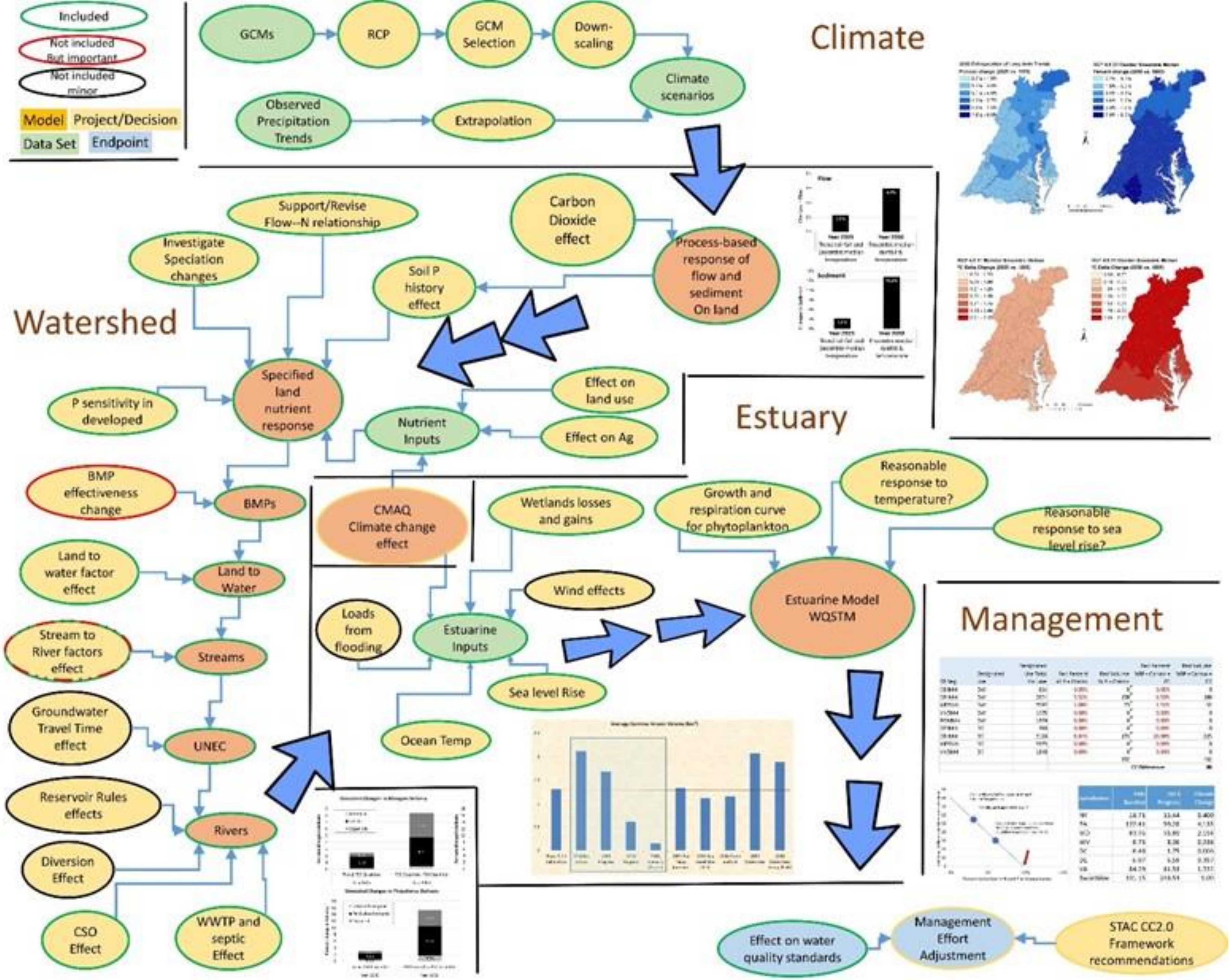
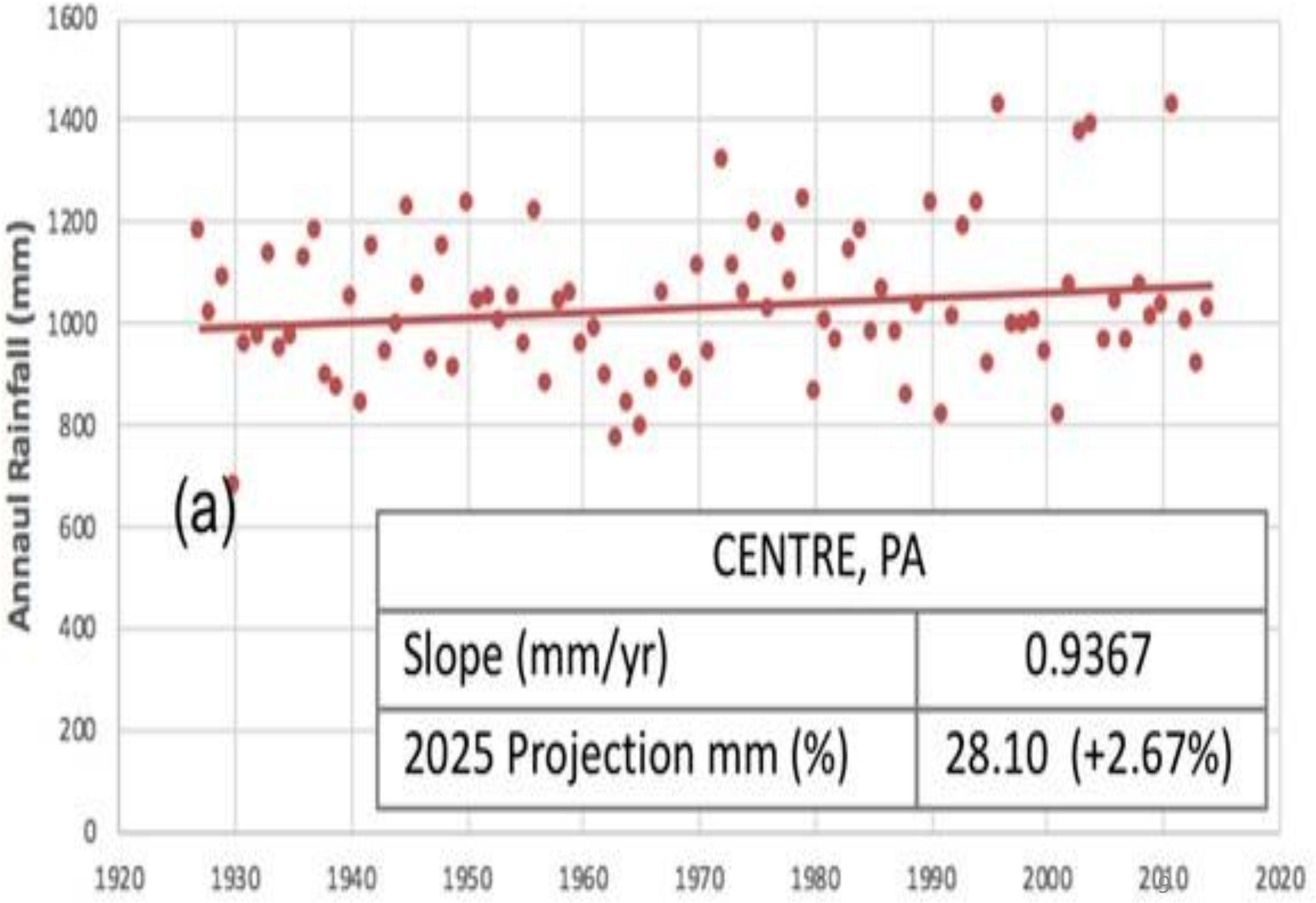

Included
Not included But important
Not included minor
Model
Project/Decision
Data Set
Endpoint
GCMs
RCP
GCM Selection
Down-scaling
Climate
Climate scenarios
Observed Precipitation Trends
Extrapolation
Carbon Dioxide effect
Process-based response of flow and sediment On land
Support/Revise Flow--N relationship
Investigate Speciation changes
Soil P history effect
Watershed
Specified land nutrient response
P sensitivity in developed
Effect on land use
Nutrient Inputs
Effect on Ag
Estuary
BMP effectiveness change
BMPs
CMAQ Climate change effect
Wetlands losses and gains
Growth and respiration curve for phytoplankton
Reasonable response to temperature?
Reasonable response to sea level rise?
Land to water factor effect
Land to Water
Wind effects
Estuarine Model WQSTM
Management
Loads from flooding
Estuarine Inputs
Stream to River factors effect
Streams
Sea level Rise
Groundwater Travel Time effect
UNEC
Ocean Temp
Reservoir Rules effects
Rivers
Diversion Effect
CSO Effect
WWTP and septic Effect
Effect on water quality standards
Management Effort Adjustment
STAC CC2.0 Framework recommendations

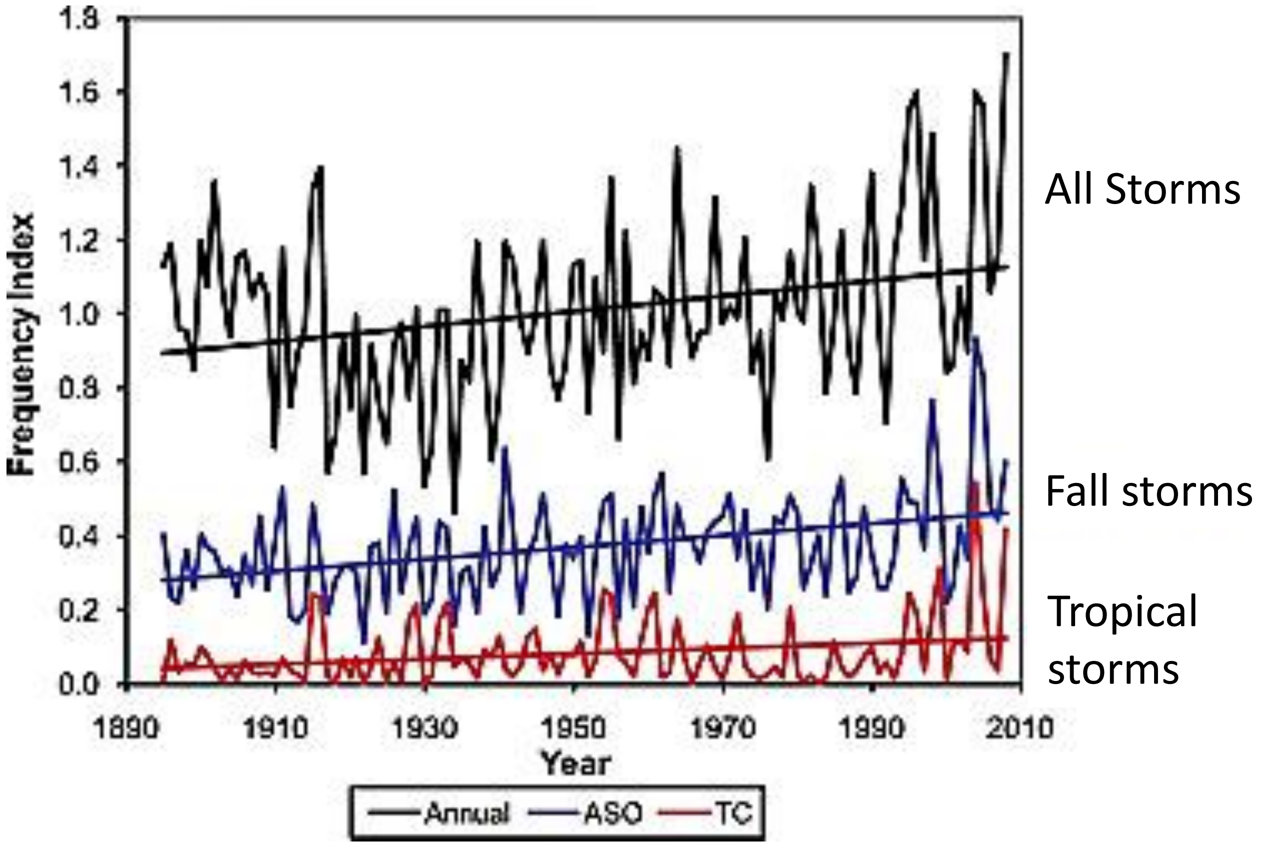
2025 Precipitation – Using observed trends

- regression of annual rainfall
- Applied as a percentage change to each month of rainfall



Climate delta change from 1995

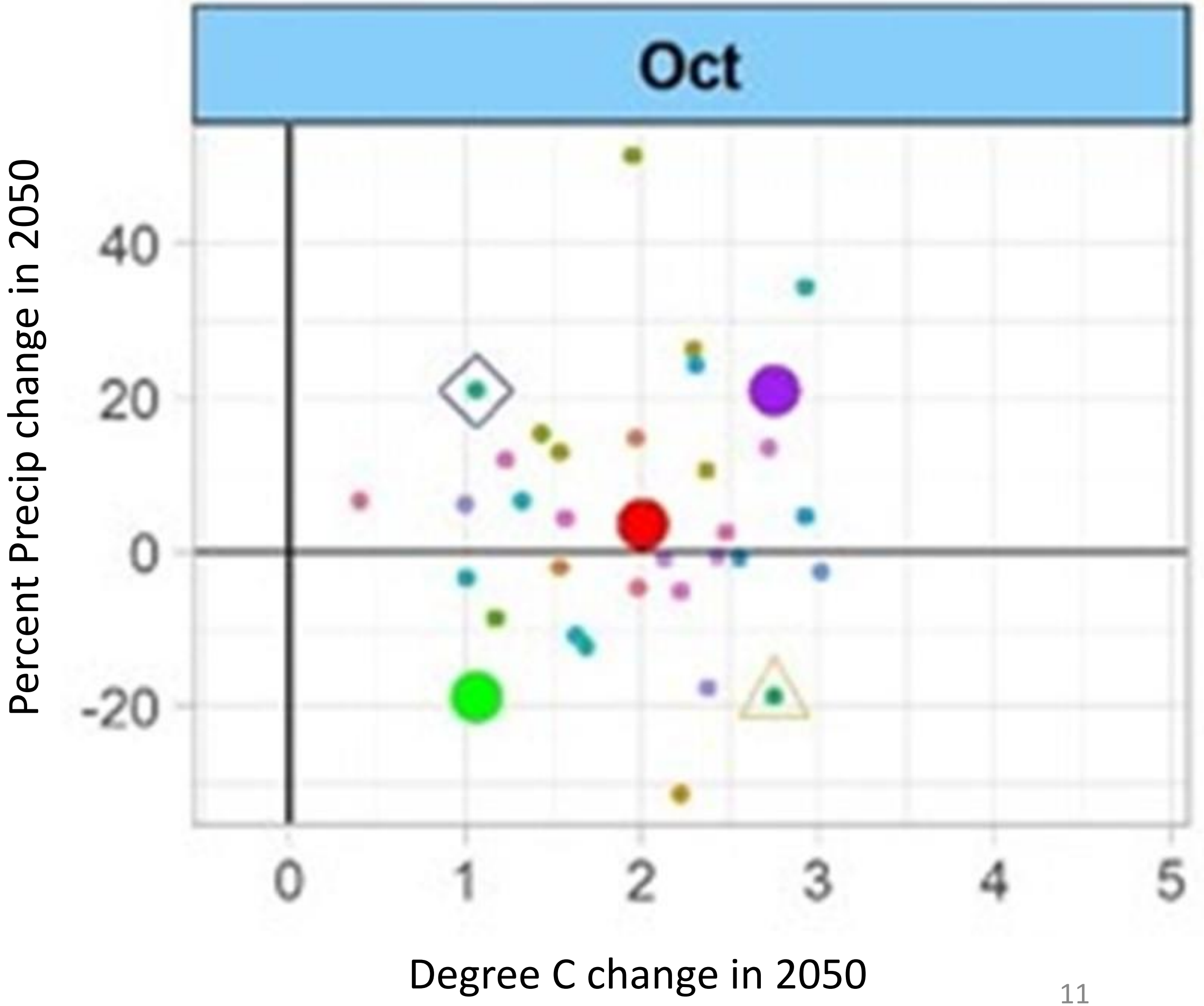
More volume into higher intensity events



National average heavy precipitation event index (HPEI) for the entire year (annual, black), for August through October (ASO, blue), and for heavy events associated with tropical cyclones (TC, red). [Kunkel et al., 2010]

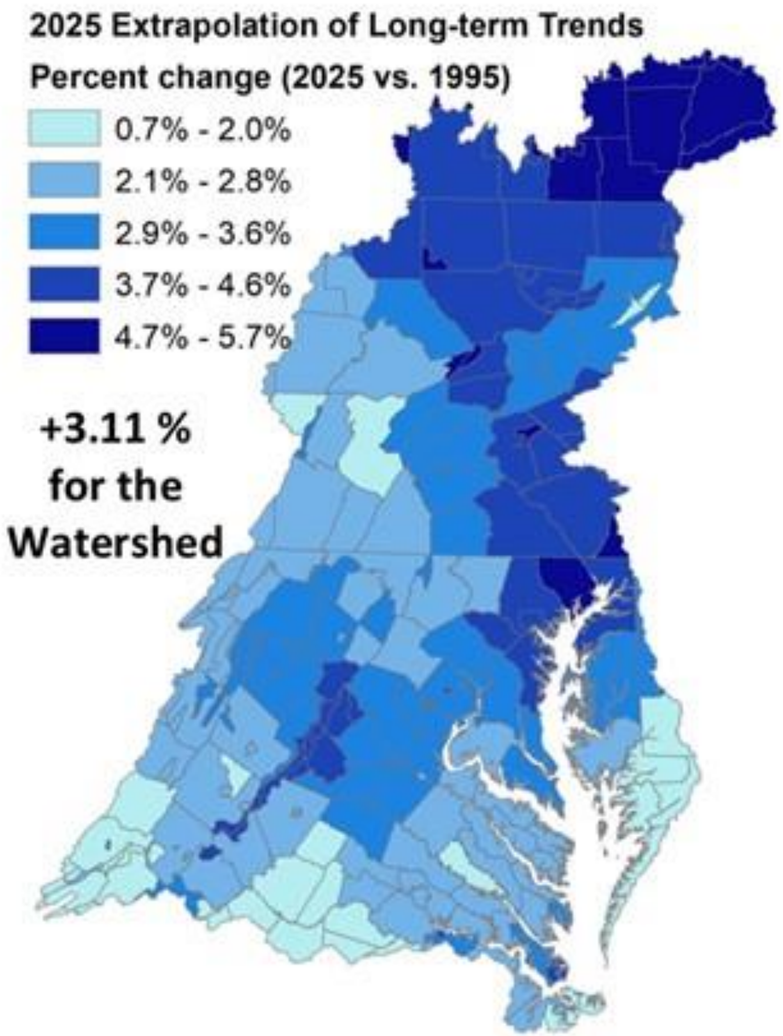
2025 Temperature and 2050 precip & Temperature – GCM ensemble

- Select median monthly change
- 10th and 90th for uncertainty
- Temperature applied as constant degree addition

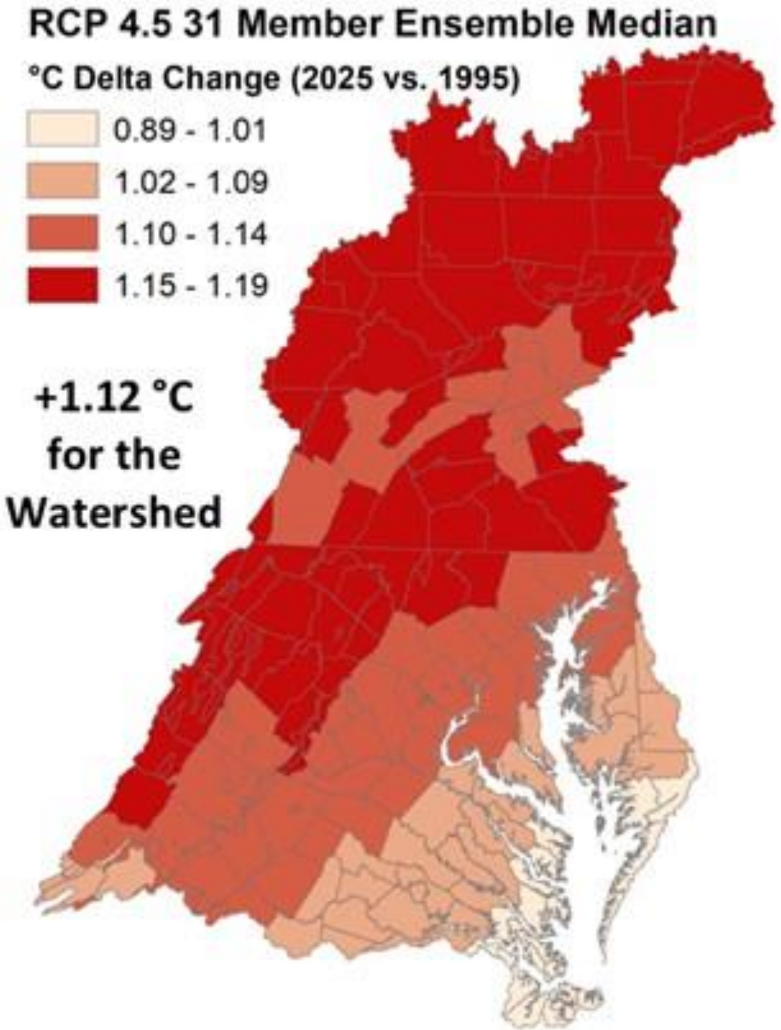


2025 Climate vs 1995 Climate

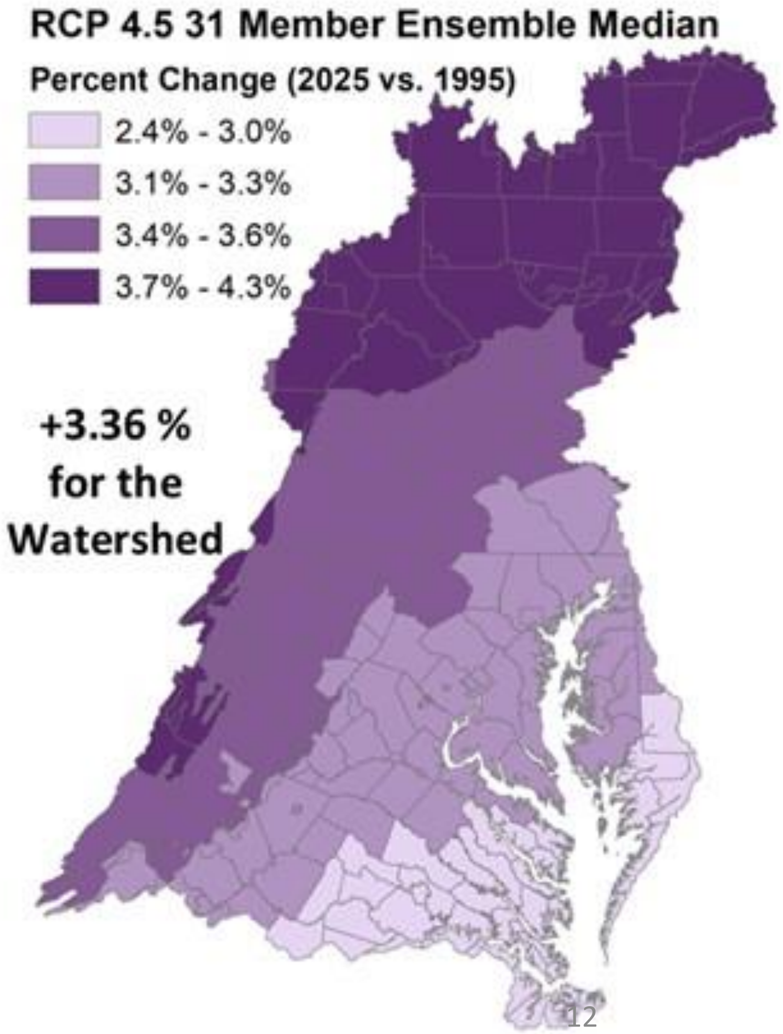
Precipitation



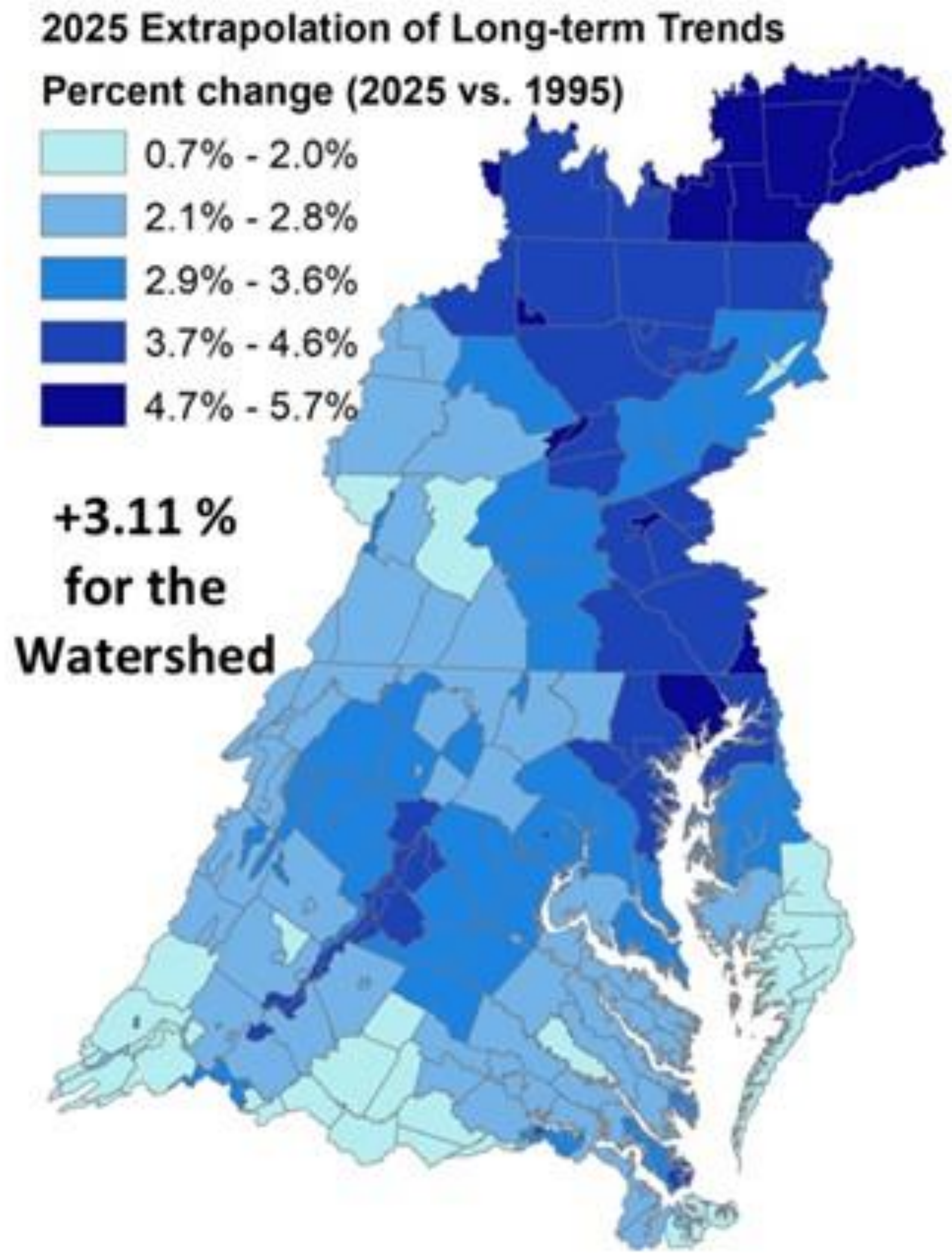
Temperature



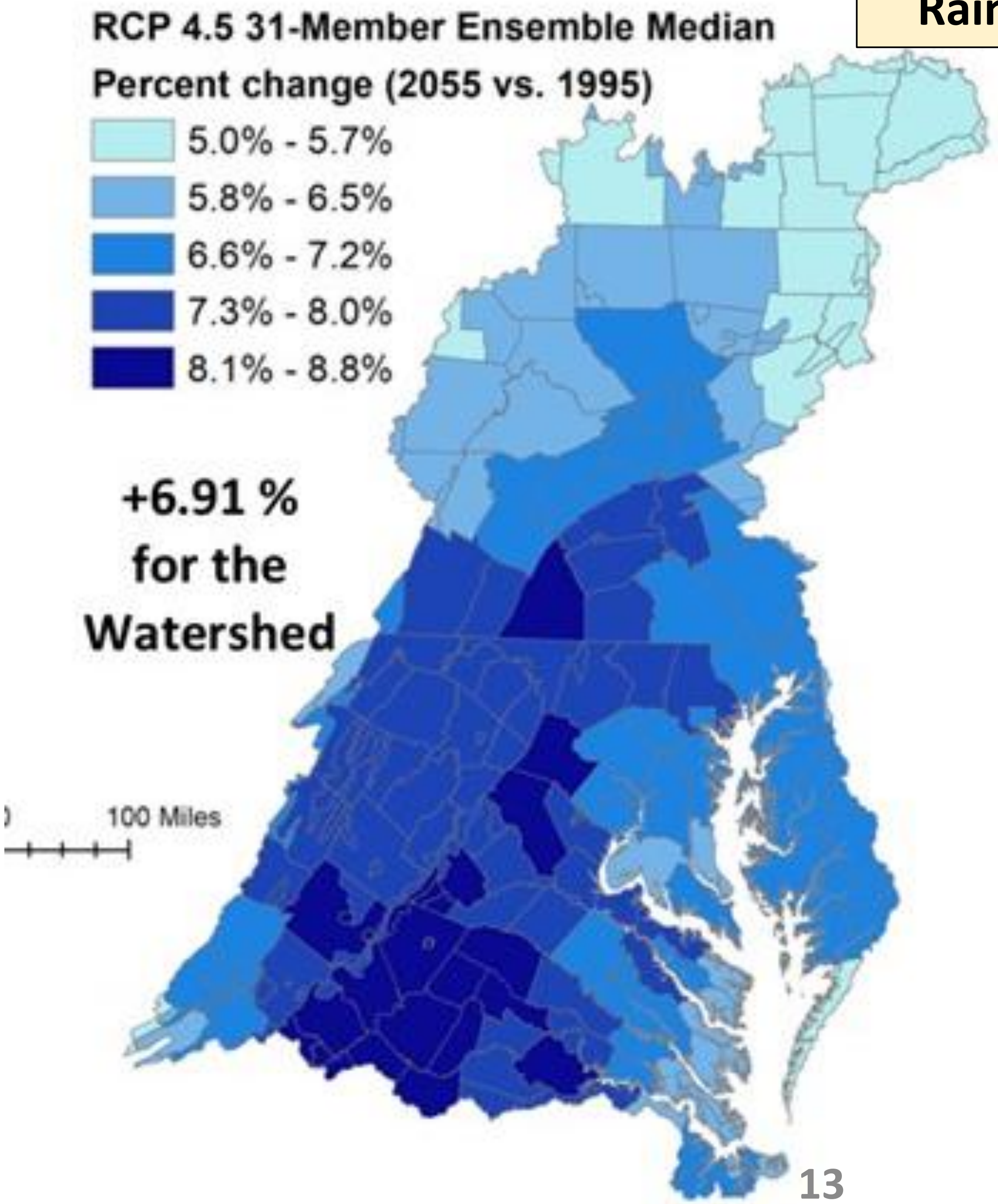
PET



Rainfall



2025 Extrapolation of Long-term Trends
Percent change (2025 vs. 1995)
0.7% - 2.0%
2.1% - 2.8%
2.9% - 3.6%
3.7% - 4.6%
4.7% - 5.7%
+3.11 %
for the
Watershed



RCP 4.5 31-Member Ensemble Median
Percent change (2055 vs. 1995)
5.0% - 5.7%
5.8% - 6.5%
6.6% - 7.2%
7.3% - 8.0%
8.1% - 8.8%
+6.91 %
for the
Watershed
100 Miles

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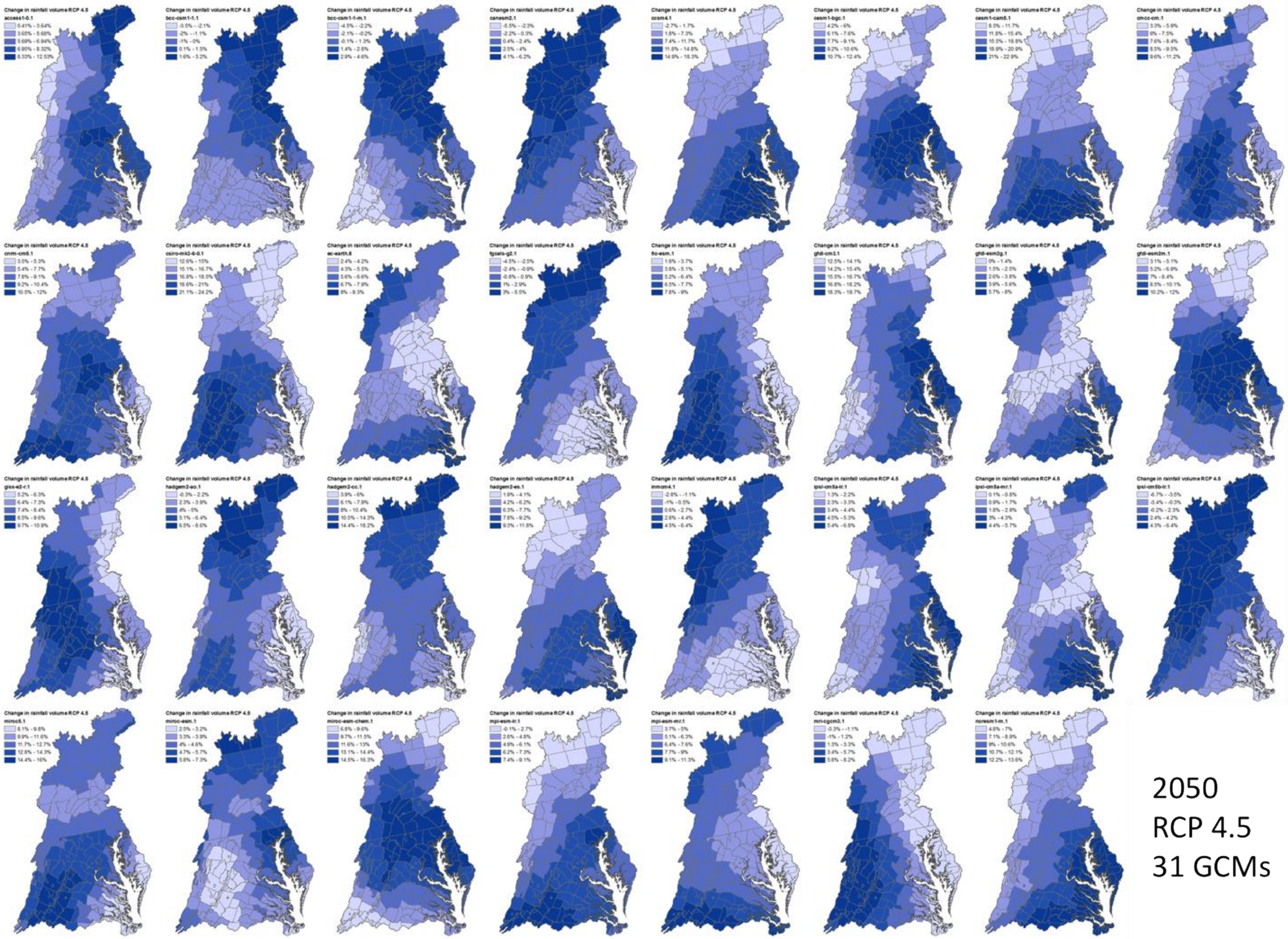
Ensemble of Downscaled Global Climate Models

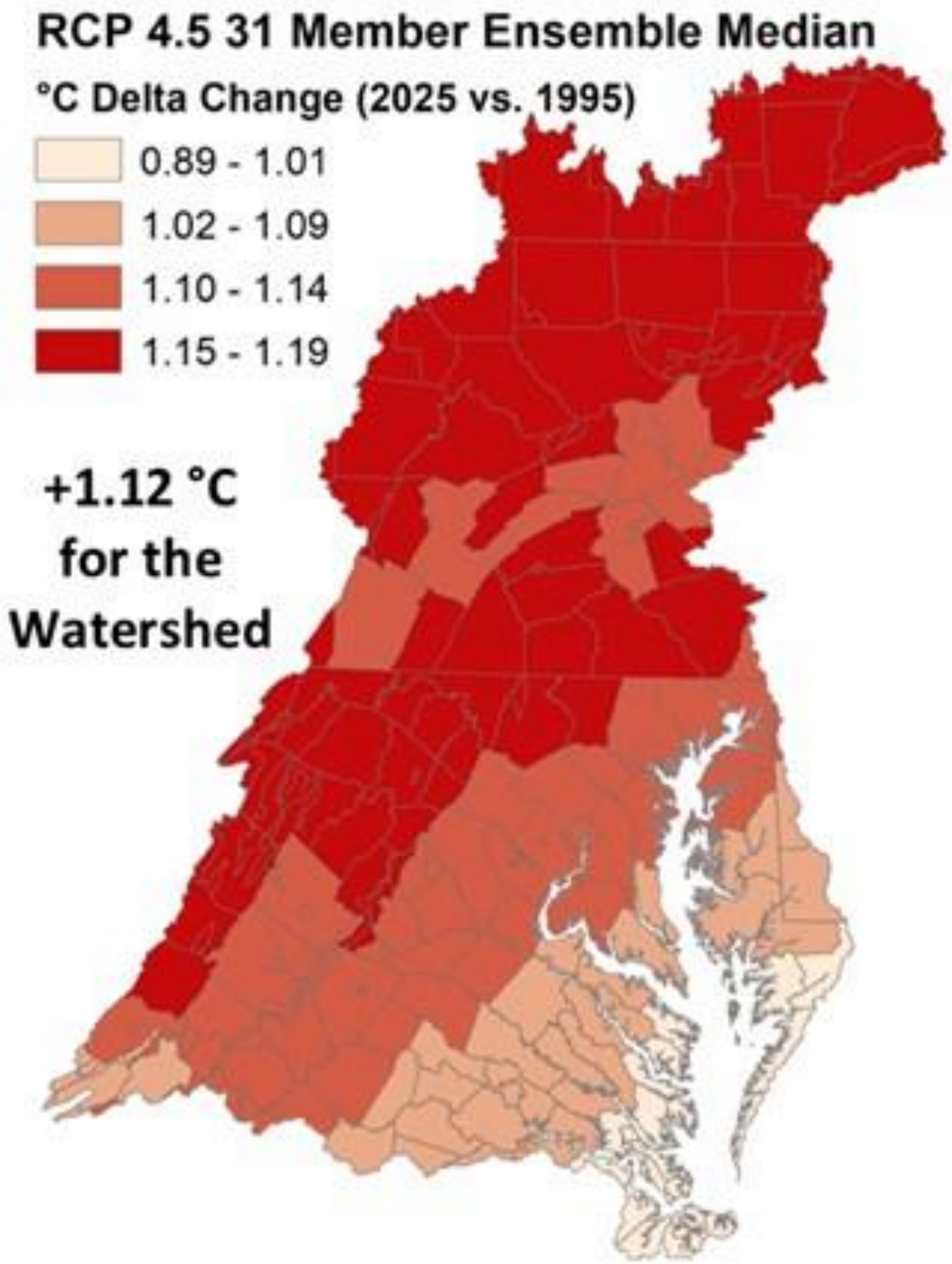


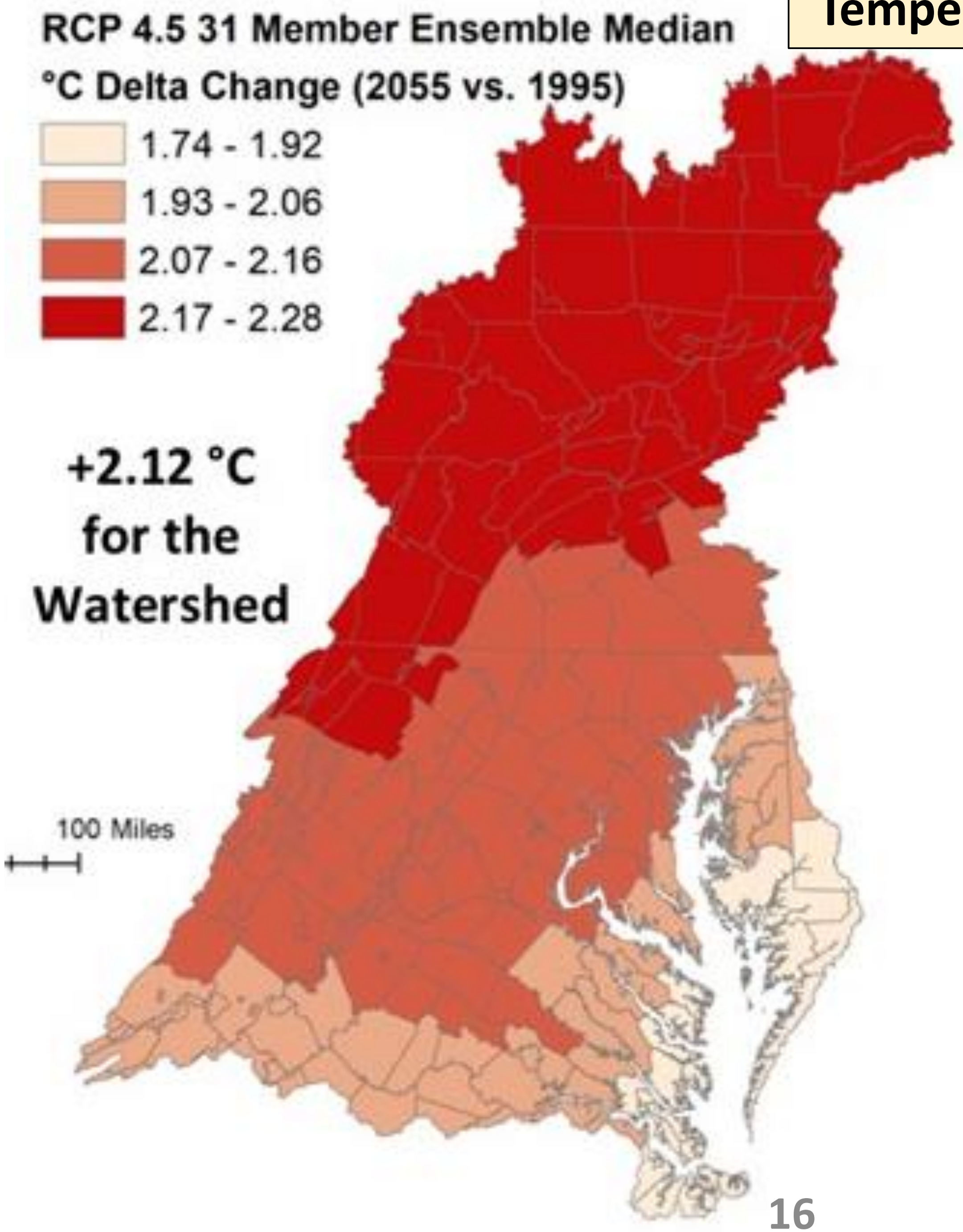
2050
RCP 4.5
31 GCMs

Urban Stormwater projects

- GIT-Funded – Piloting the Development of Probabilistic Intensity Duration Frequency (IDF) Curves for Chesapeake Bay Watershed
  - (March 2021)
- Chesapeake Stormwater Network: Urban stormwater BMP climate vulnerability assessment
  - (October 2020)

Temperature





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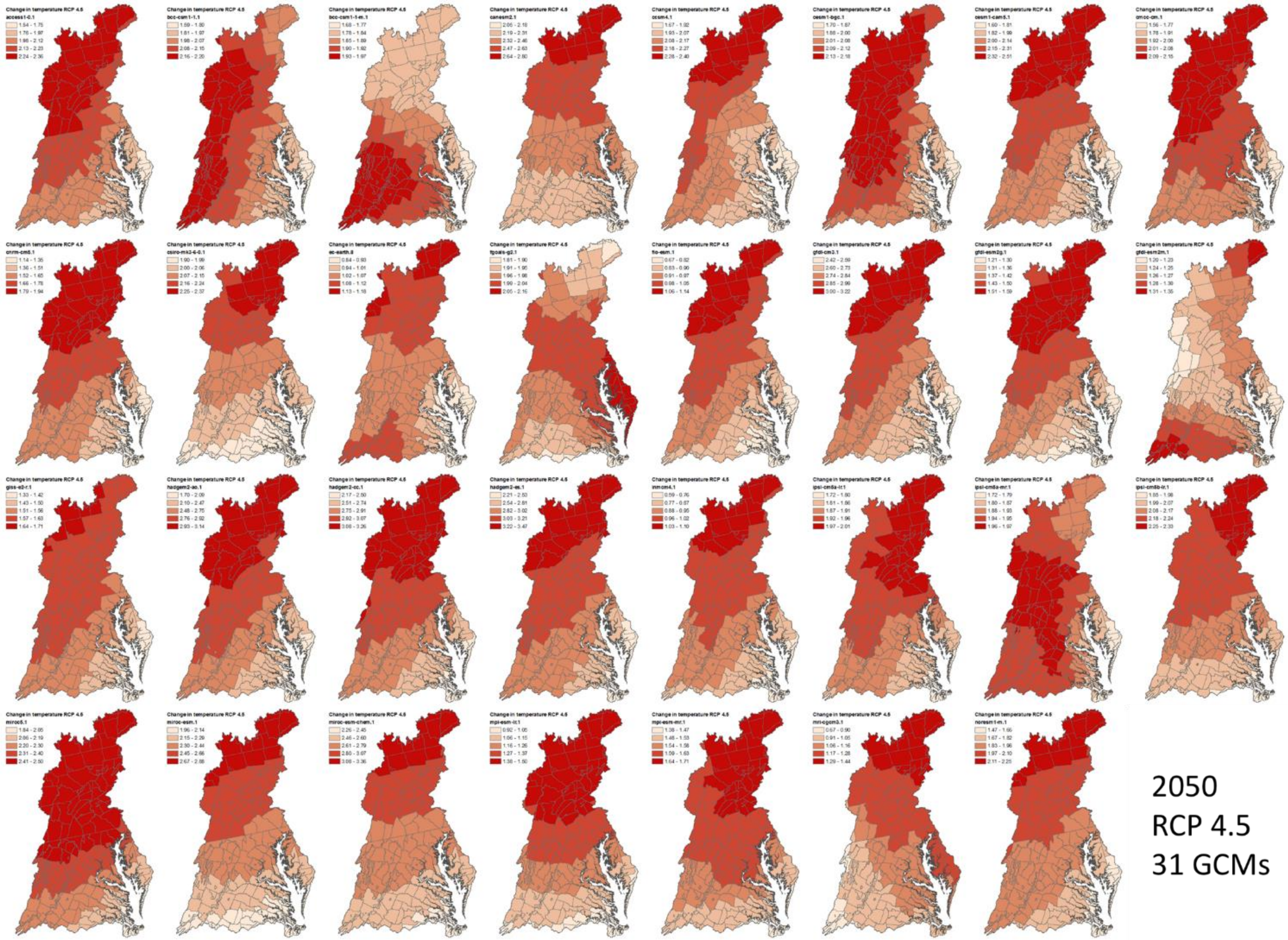
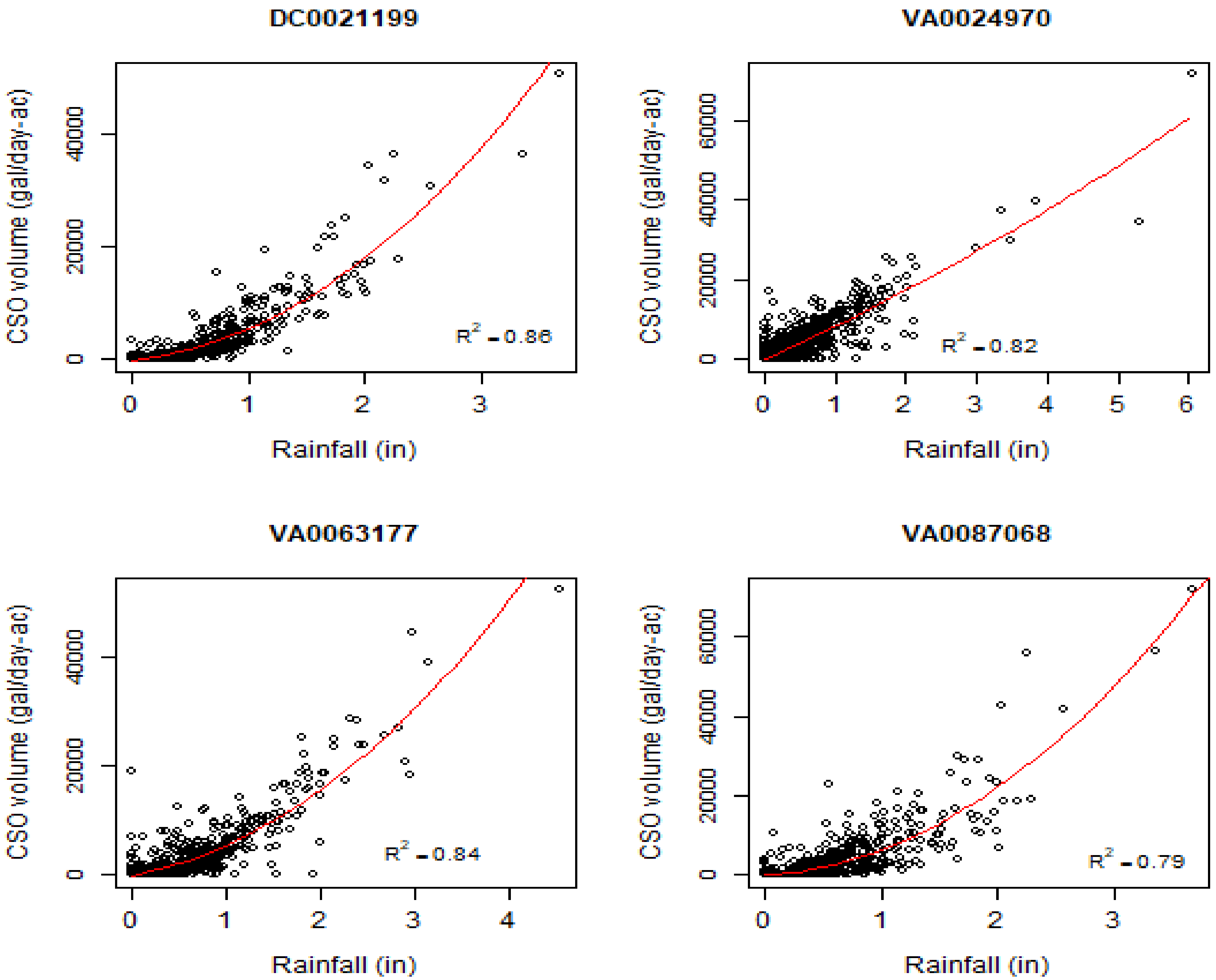
Ensemble of Downscaled Global Climate Models



2050
RCP 4.5
31 GCMs

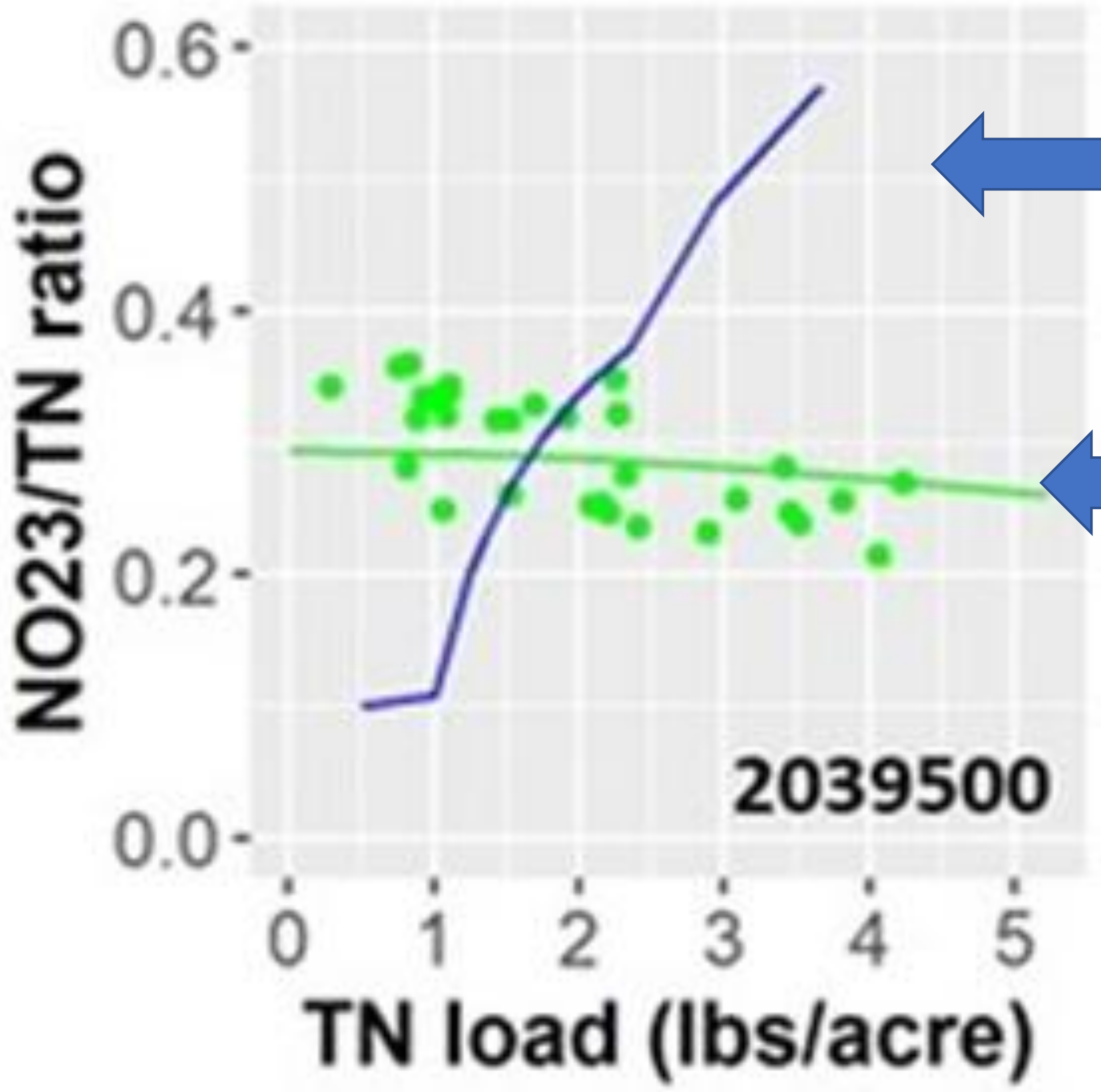
CSO effect


DC0021199
CSO volume (gal/day-ac)
0
20000
40000
0
1
2
3
Rainfall (in)
R² = 0.86
VA0024970
CSO volume (gal/day-ac)
0
20000
40000
60000
0
1
2
3
4
5
6
Rainfall (in)
R² = 0.82
VA0063177
CSO volume (gal/day-ac)
0
20000
40000
0
1
2
3
4
Rainfall (in)
R² = 0.84
VA0087068
CSO volume (gal/day-ac)
0
20000
40000
60000
0
1
2
3
Rainfall (in)
R² = 0.79

Nutrient effect

- Nitrogen
  - No change concentration of TN
  - more flow = more transport
- Phosphorus
  - Already tied to surface runoff and sediment washoff
  - Small negative feedback with depleted soils

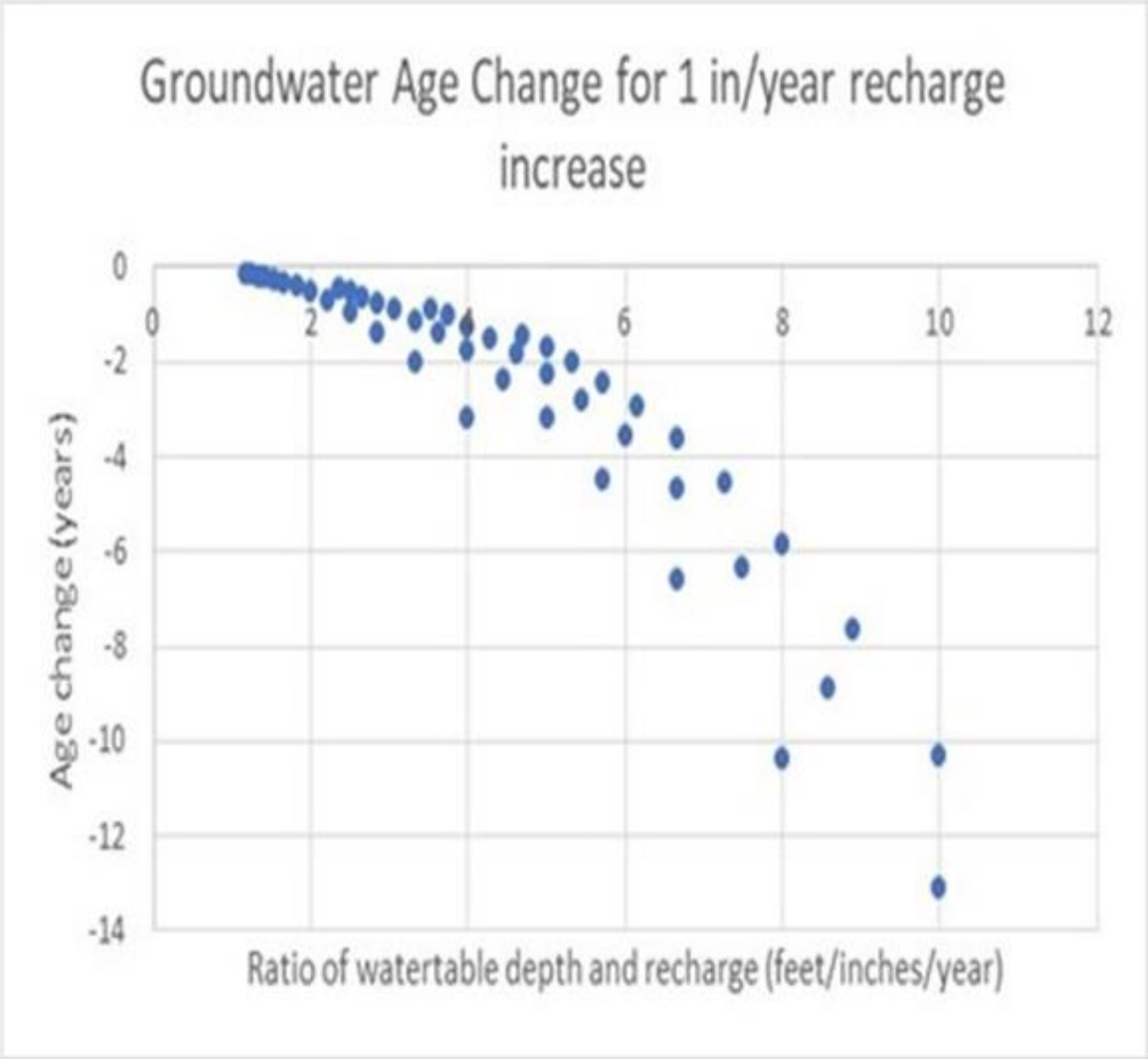
Nitrate increases more slowly than TN



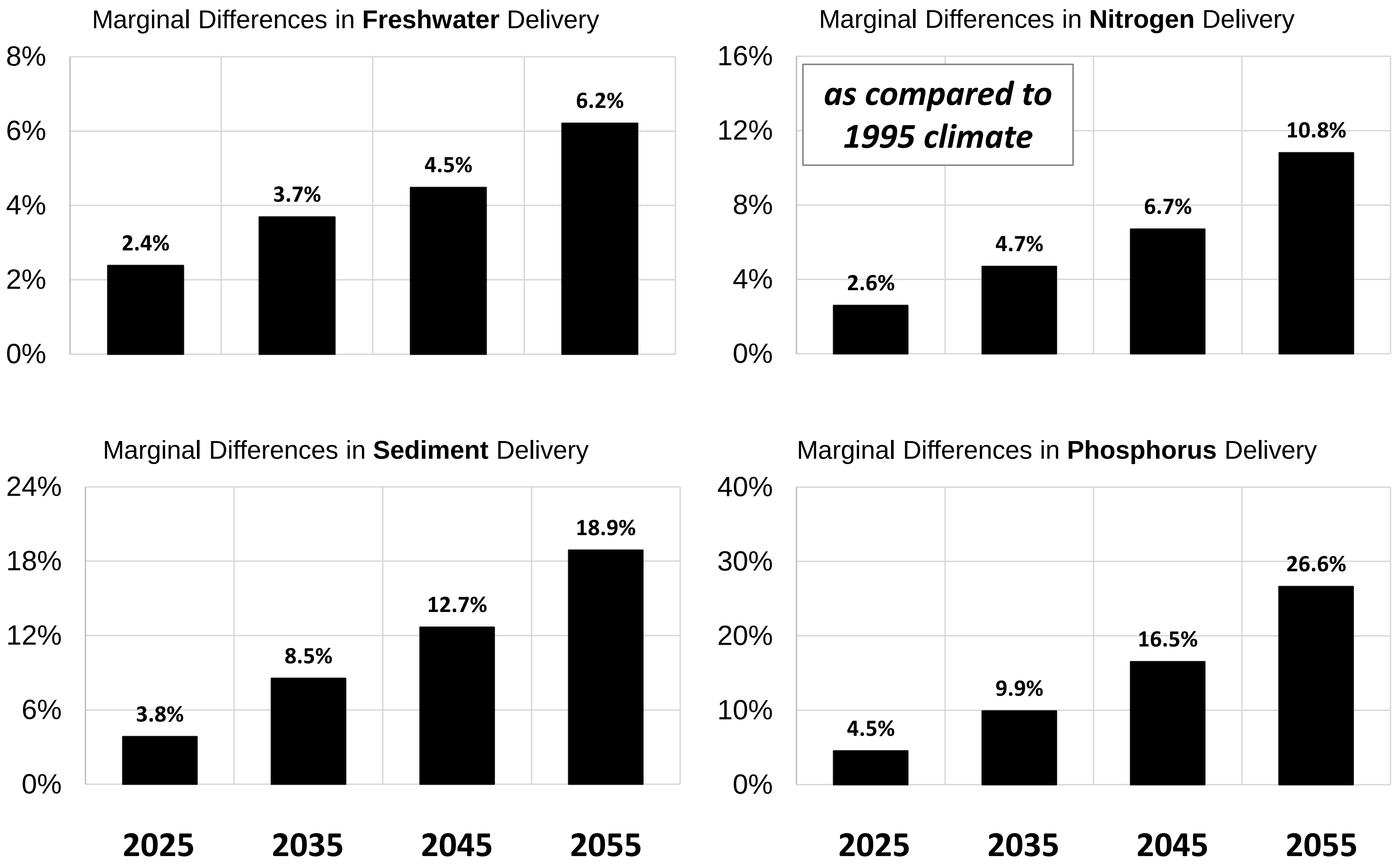
Across sites

Single site

Younger groundwater

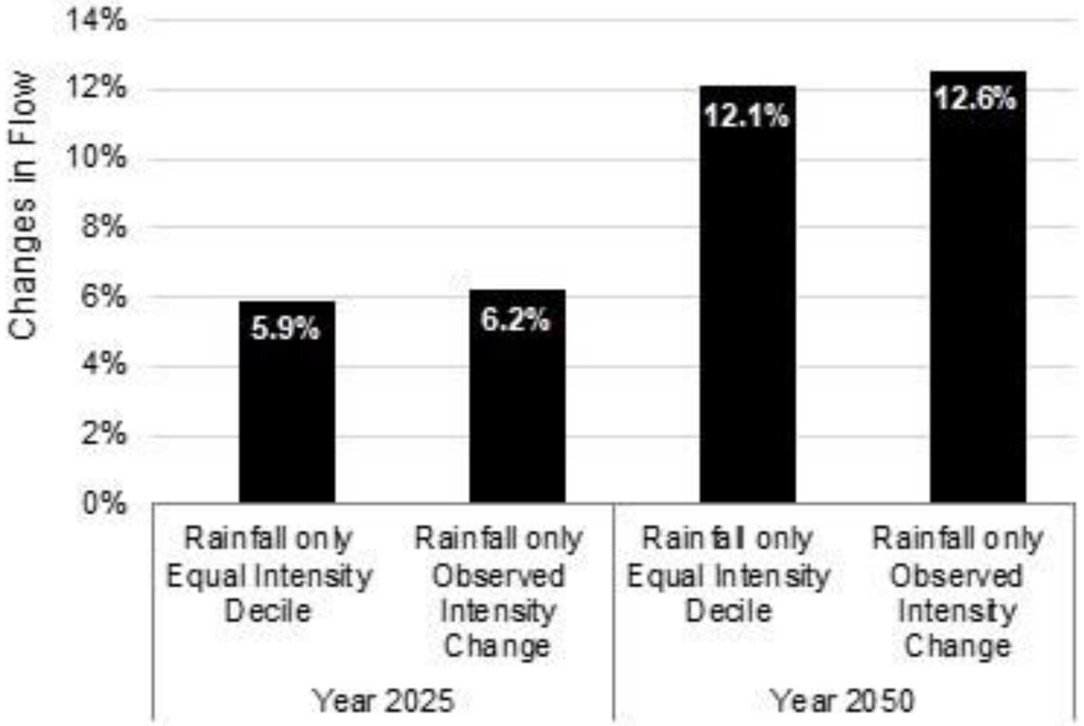


Estimated Water Quality Responses

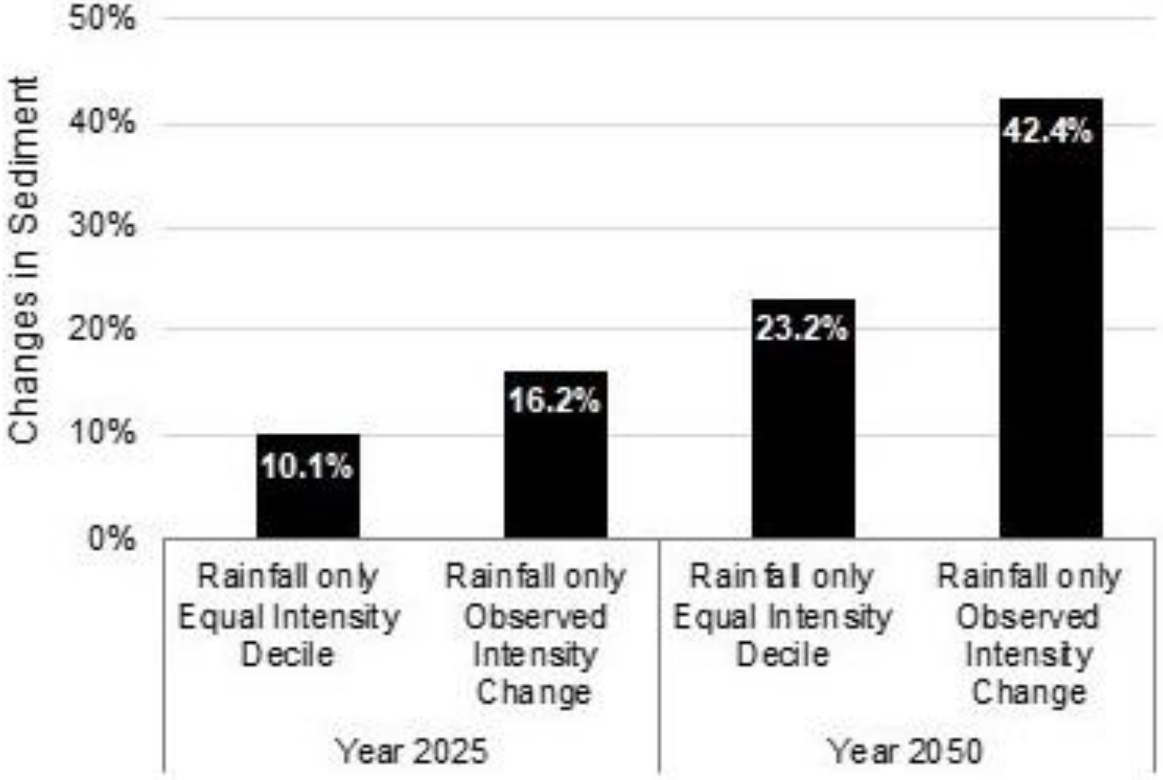


Flashiness of rainfall influences sediment

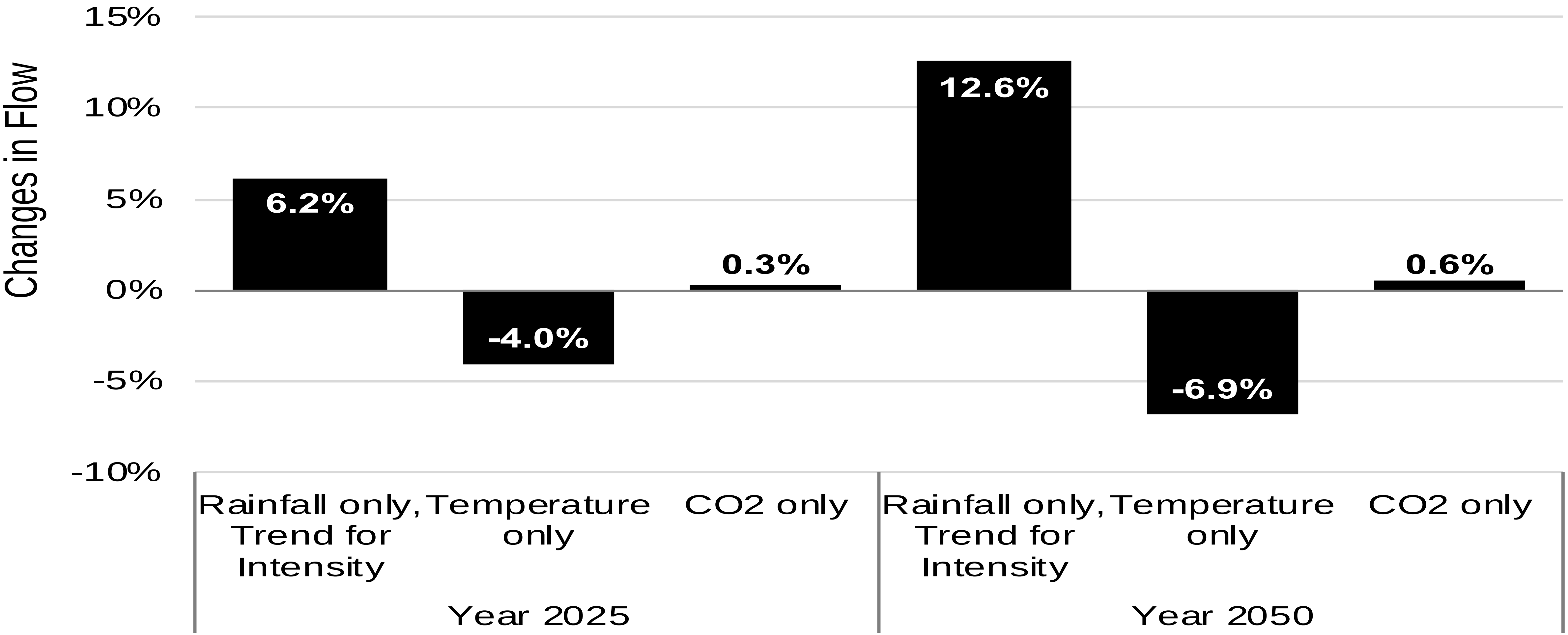
Flow



Sediment

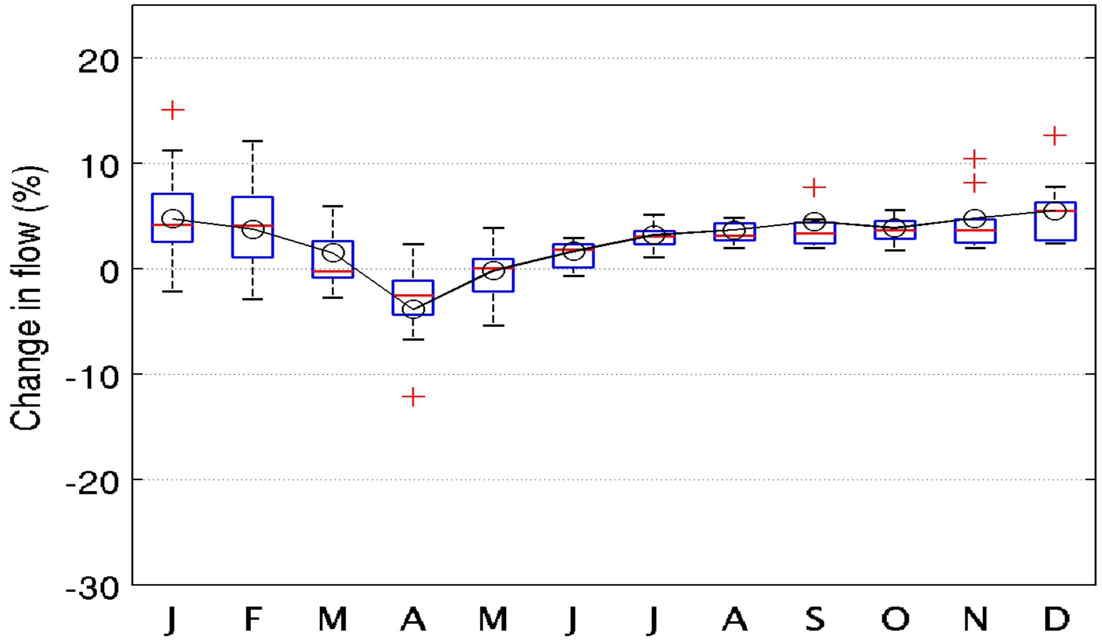


Components of flow change

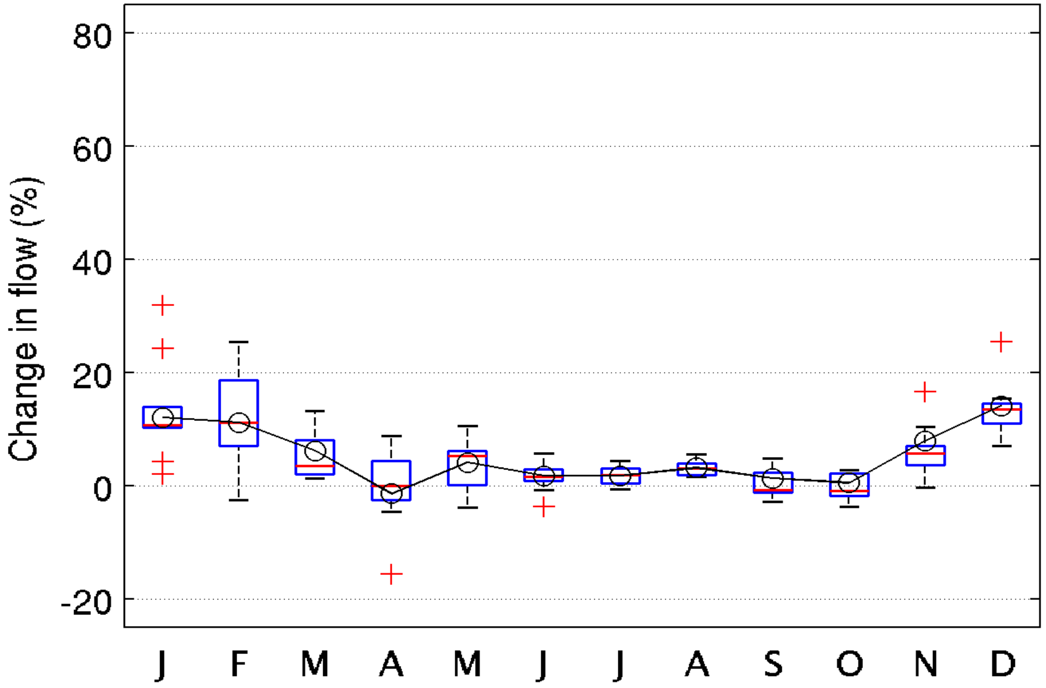


Seasonal Changes in flow

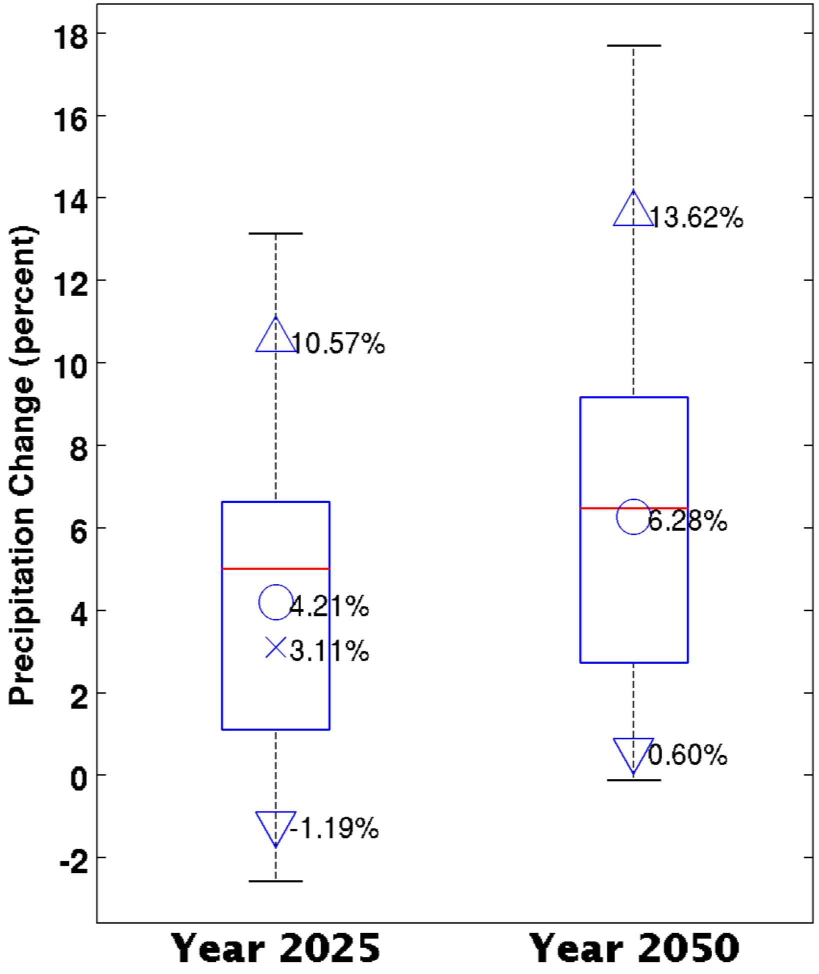
2025

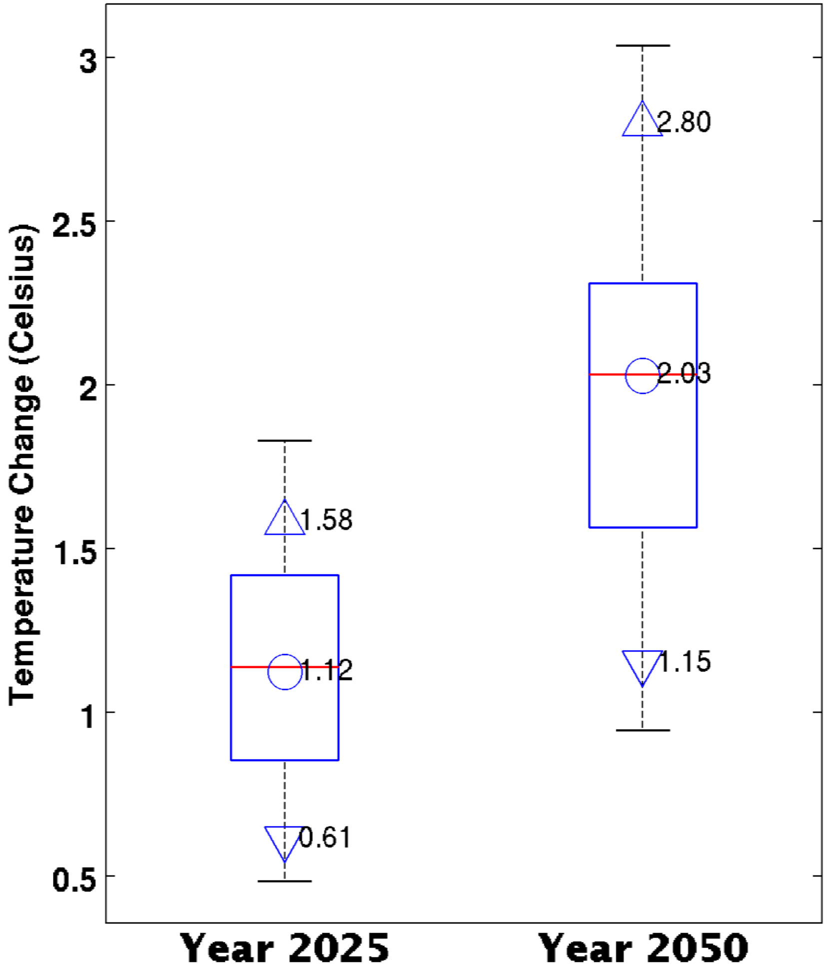


2055



Climate Model uncertainty





Climate Change Scenarios

Air-temperature increase: 1.06 °C

Flow

+2.4% est. 2025

TN

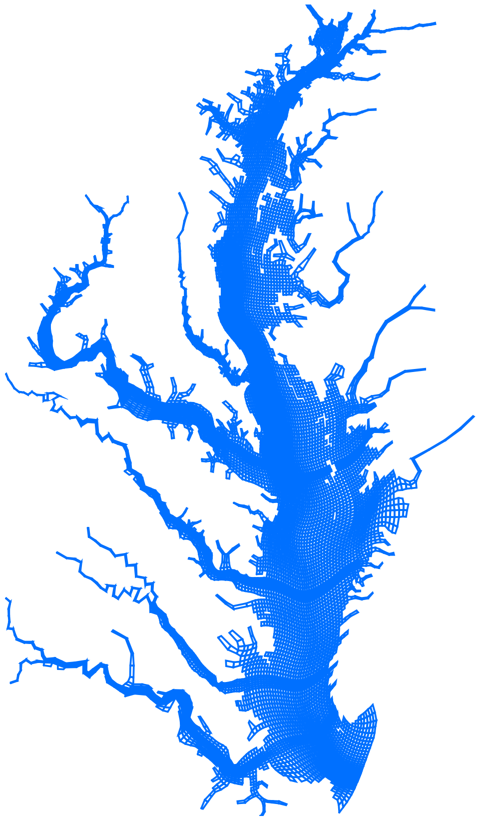
+2.6% est. 2025

TP

+4.5% est. 2025

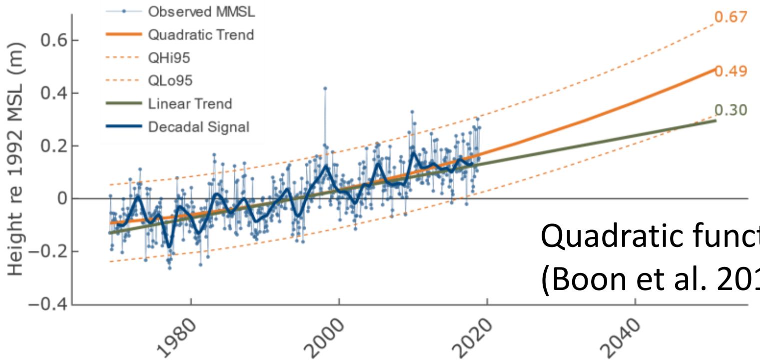
Sediment

+3.8 est. 2025

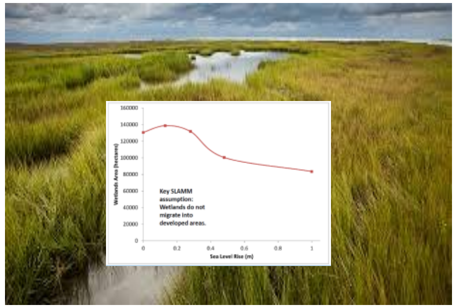


Norfolk (Sewells Point), Virginia

Sea Level Rise: 0.22m



Quadratic function (Boon et al. 2013)



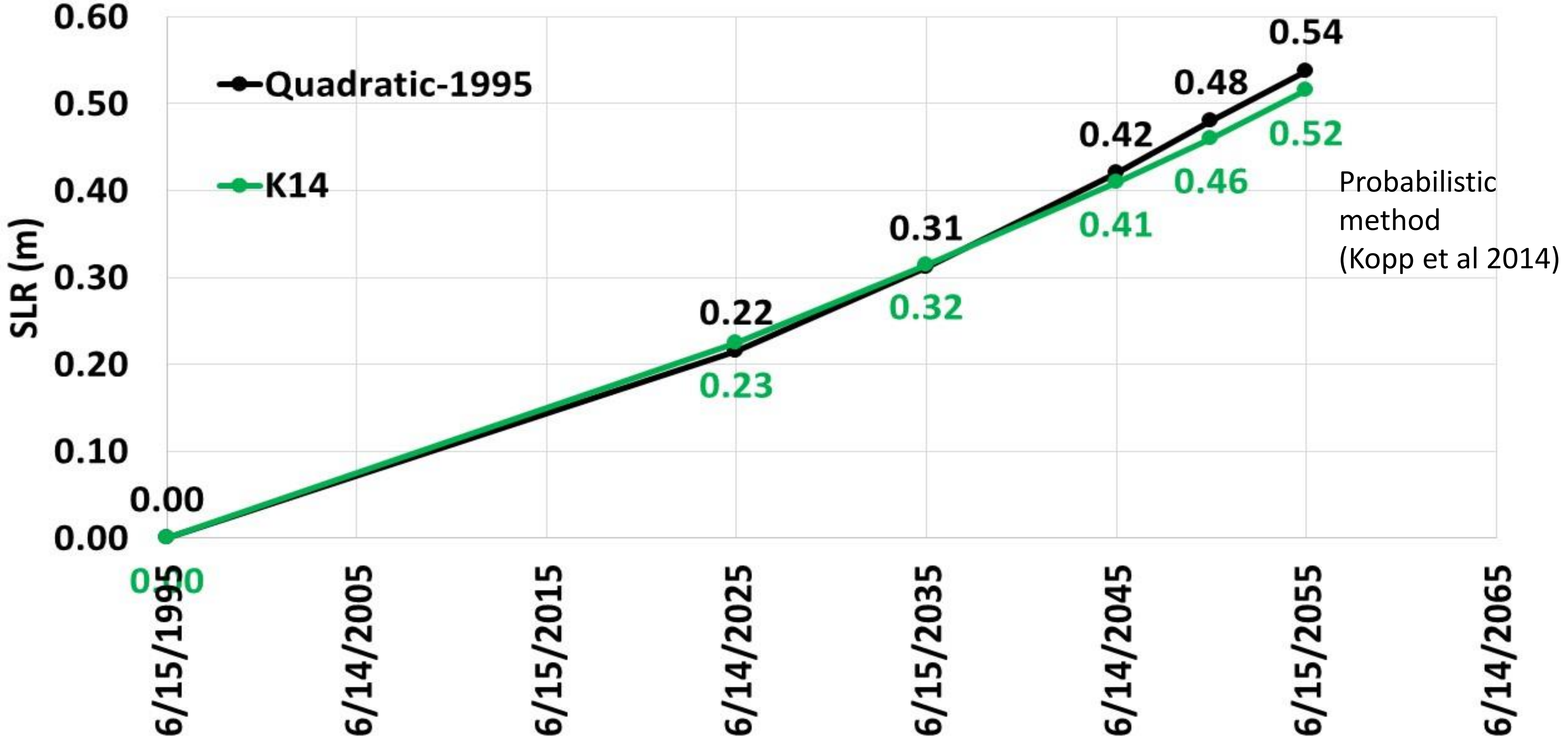
Tidal wetland change

Ocean boundary

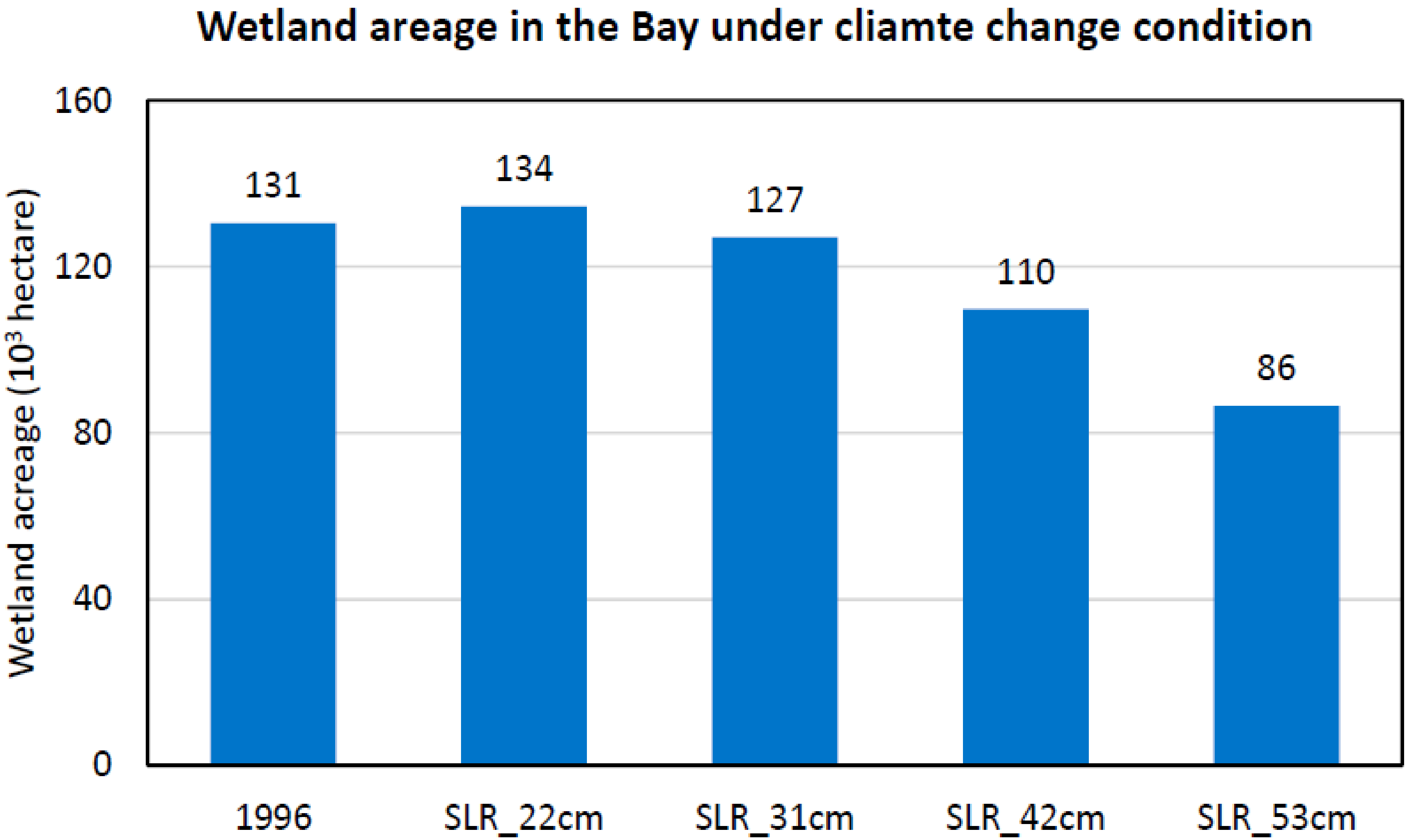
delta T: + 0.95 °C; delta S: + 0.18 psu

(Thomas et al., 2017)

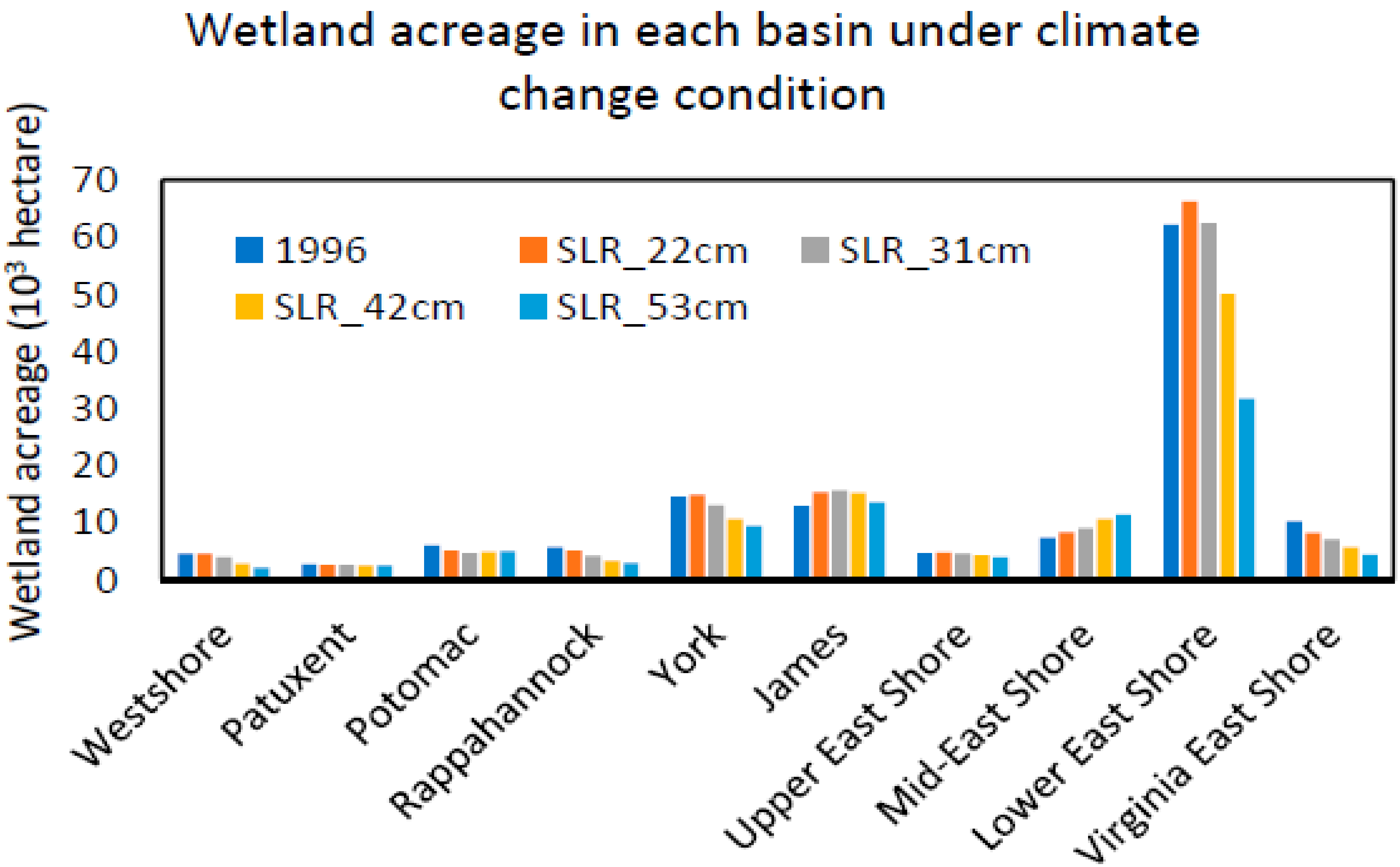
Climate Change Processes and Dependencies



Wetland Area change



Wetland Area change



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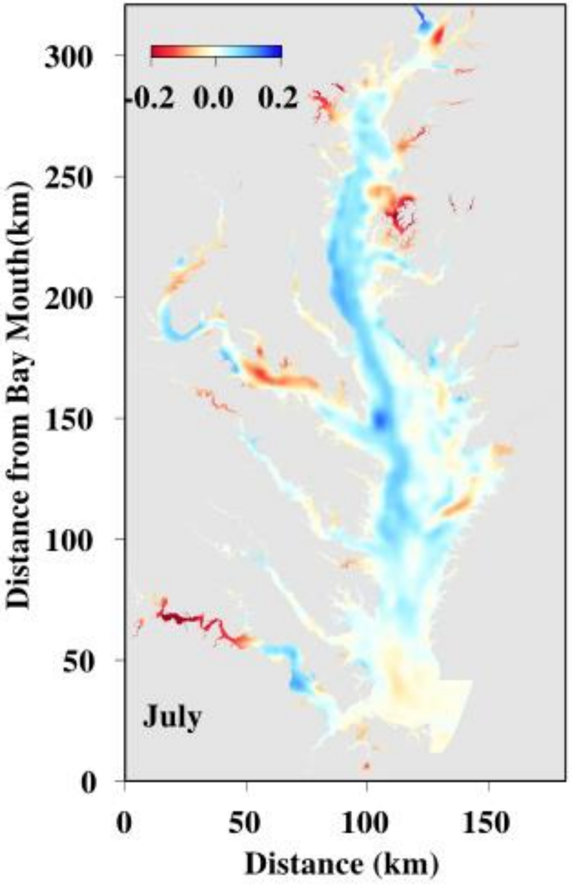
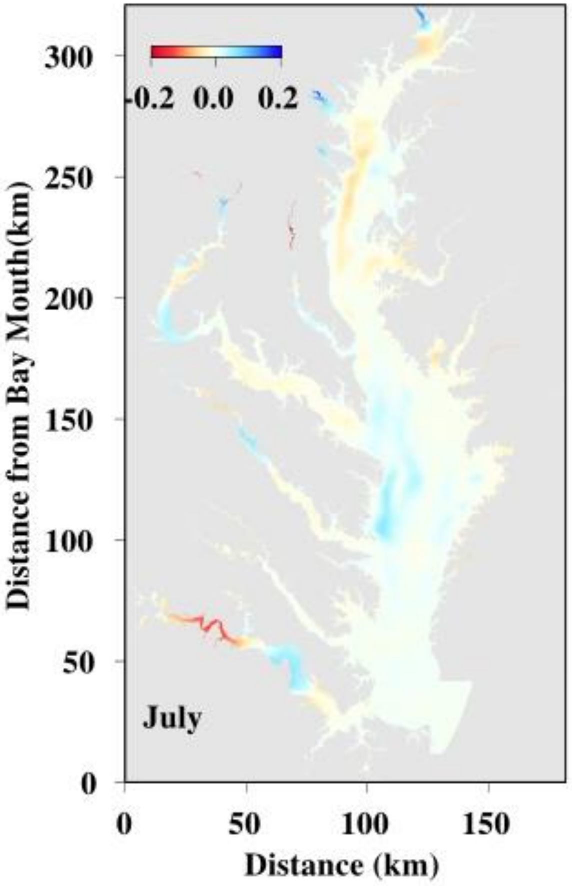
Bottom DO Change: 1995 to 2025

Keeping all other factors constant, sea level rise and increased watershed flow reduce hypoxia in the Bay, but the predominant influence are the negative impacts of increased water column temperature.

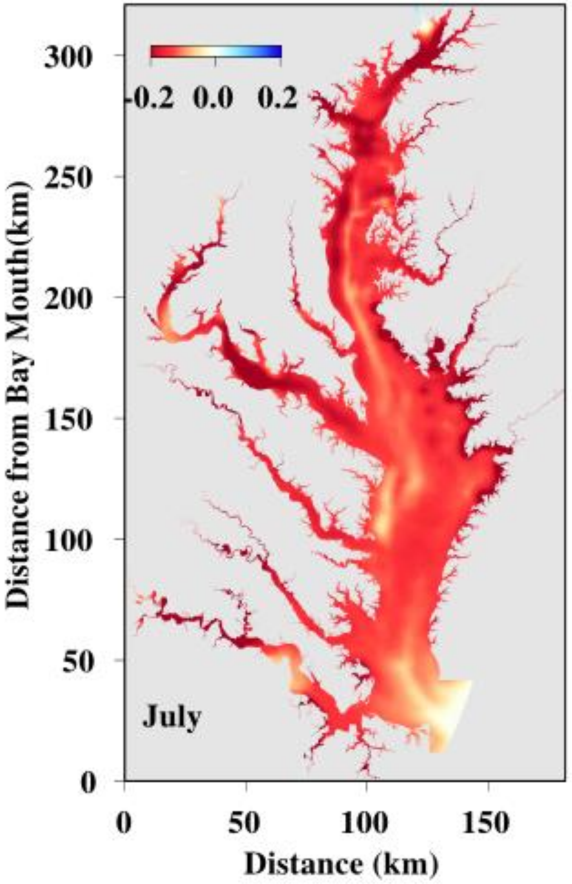
Sea Level Rise



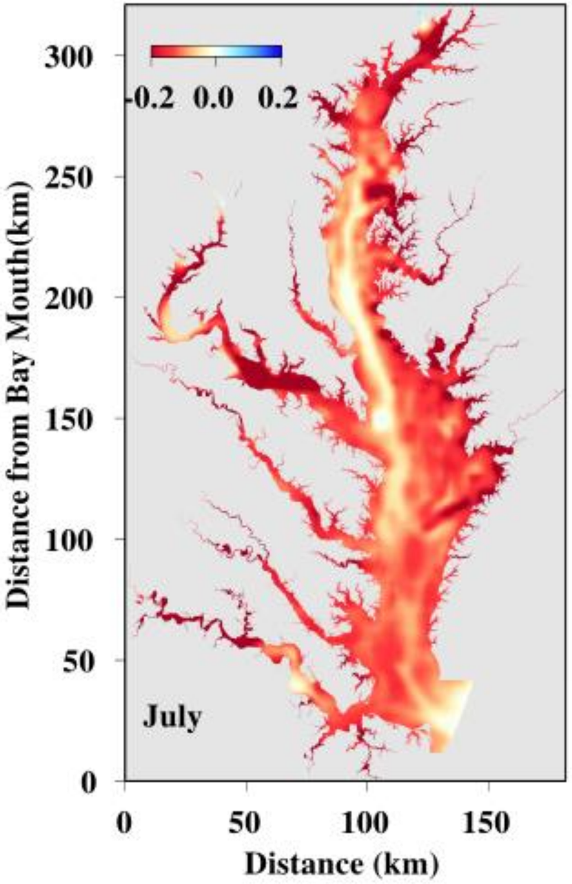
Watershed Flow



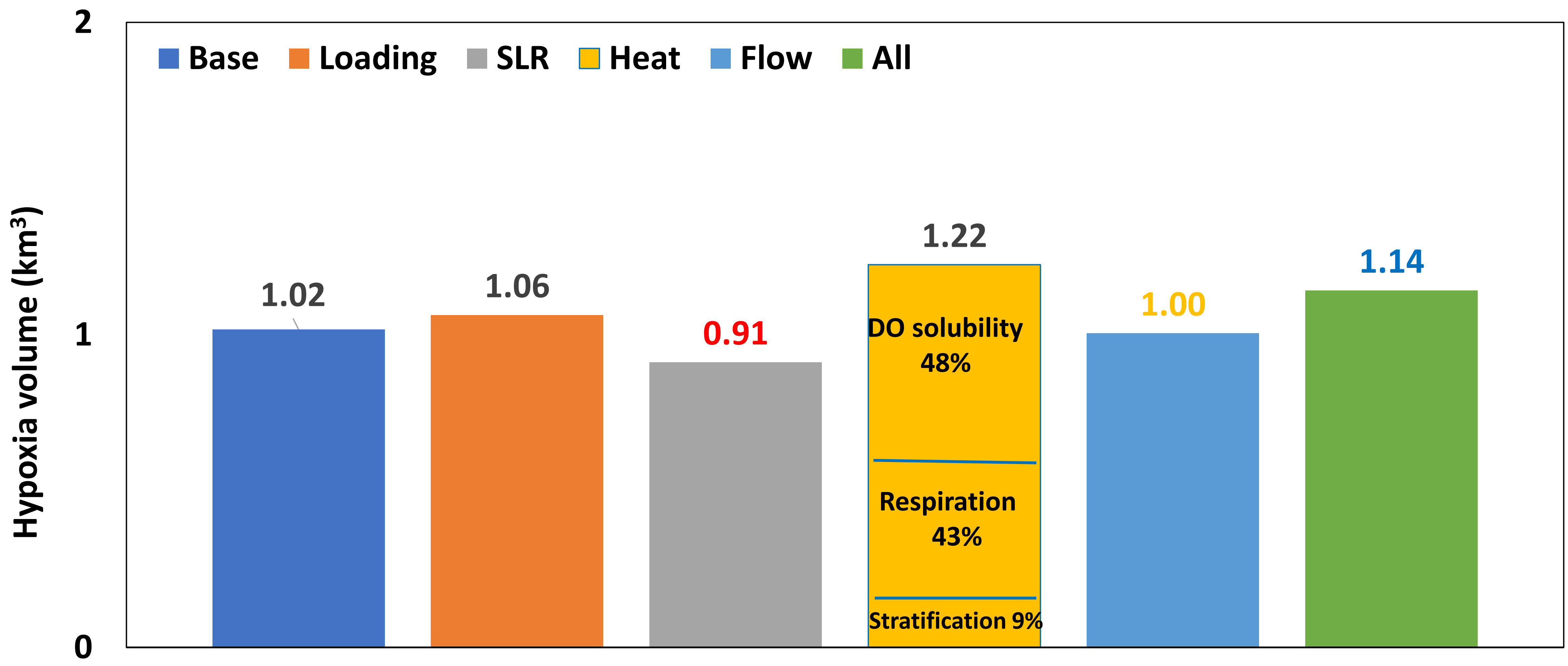
Increased Temp.



All Factors



Summer (Jun.-Sep.) hypoxia volume (<1 mg/l) 1991-2000 in the Whole Bay under WIP condition



WQGIT uses of the modeling additional load reductions

State	Nitrogen	Phosphorus
DC	0.20	0.024
DE	0.16	0.003
MD	2.13	0.143
NY	0.27	0.014
PA	2.33	0.092
VA	2.01	0.240
WV	0.14	0.010
Total	7.24	0.526

Year	Nitrogen	Phosphorus
2025	6.72	0.467
2035	11.95	0.830
2045	18.95	1.316
2055	25.45	1.768

Tradeoffs

OW DW and DC

CB Seg	Designated Use	Planning Target 1995 climate	Planning Target 2025 climate	PT + reductions 2025 climate	Change between Planning Target and Draft CC reductions
CB6PH	OW	0.13%	0.49%	0.38%	-0.25%
CB7PH	OW	0.64%	1.74%	1.43%	-0.79%
CB3MH	DW	0.05%	0.06%	0.06%	-0.01%
CB4MH	DW	5.74%	6.67%	5.89%	-0.16%
CB5MH_MD	DW	1.27%	1.79%	1.31%	-0.03%
CB5MH_VA	DW	0.00%	0.00%	0.00%	0.00%
POTMH_MD	DW	0.03%	0.06%	0.04%	-0.01%
CB3MH	DC	0.00%	0.00%	0.00%	0.00%
CB4MH	DC	6.59%	8.06%	5.23%	1.36%
CB5MH_MD	DC	0.00%	0.00%	0.00%	0.00%
CB5MH_VA	DC	0.00%	0.00%	0.00%	0.00%

Selected Limitations

- Performed for decision purposes. Emphasis on the mean, not the uncertainty
- Shallow areas were highly affected by climate scenarios, but the estuarine model was built and tuned for the mainstem and large tidal rivers

Potential uses

- Watershed
  - Observed trend and model projected rainfall data
  - Projected flow and temperature statistics in rivers (100 cfs+)
  - Estimate of sediment and nutrient changes
- Tidal
  - Changes in temperature, oxygen, salinity
  - Could be applied to habitat models